An ultrasonic sensor measures the river level for gravity discharge. If river levels are high, the gravity diversion gate is closed and the pumped diversion channel gate is opened. The wet well diversion gate is also used to maintain the influent channel level, working with the flow control gate. Discharge pumps are activated automatically based on wet well level. Flap gates are also installed on both the gravity and pumped diversion outfalls to restrict river water from entering the system.

Flow through the station is measured by an ultrasonic device at the parshall flume. There is also an ultrasonic depth device in the influent channel, which is used to modulate the flow control and diversion gates. CSO diversion flows are estimated using the influent channel depth and an orifice equation for flow past the gravity diversion gate. Pumped flow is monitored using the mag meter along the pump discharge outlet pipe.

Warren CSO Diversion Station

This facility is located along the Concord River in the downtown area, adjacent to the UMass Lowell Convention Center parking garage, and includes a building and below-ground levels. Figure 2-20 shows a schematic drawing of the regulator station layout.

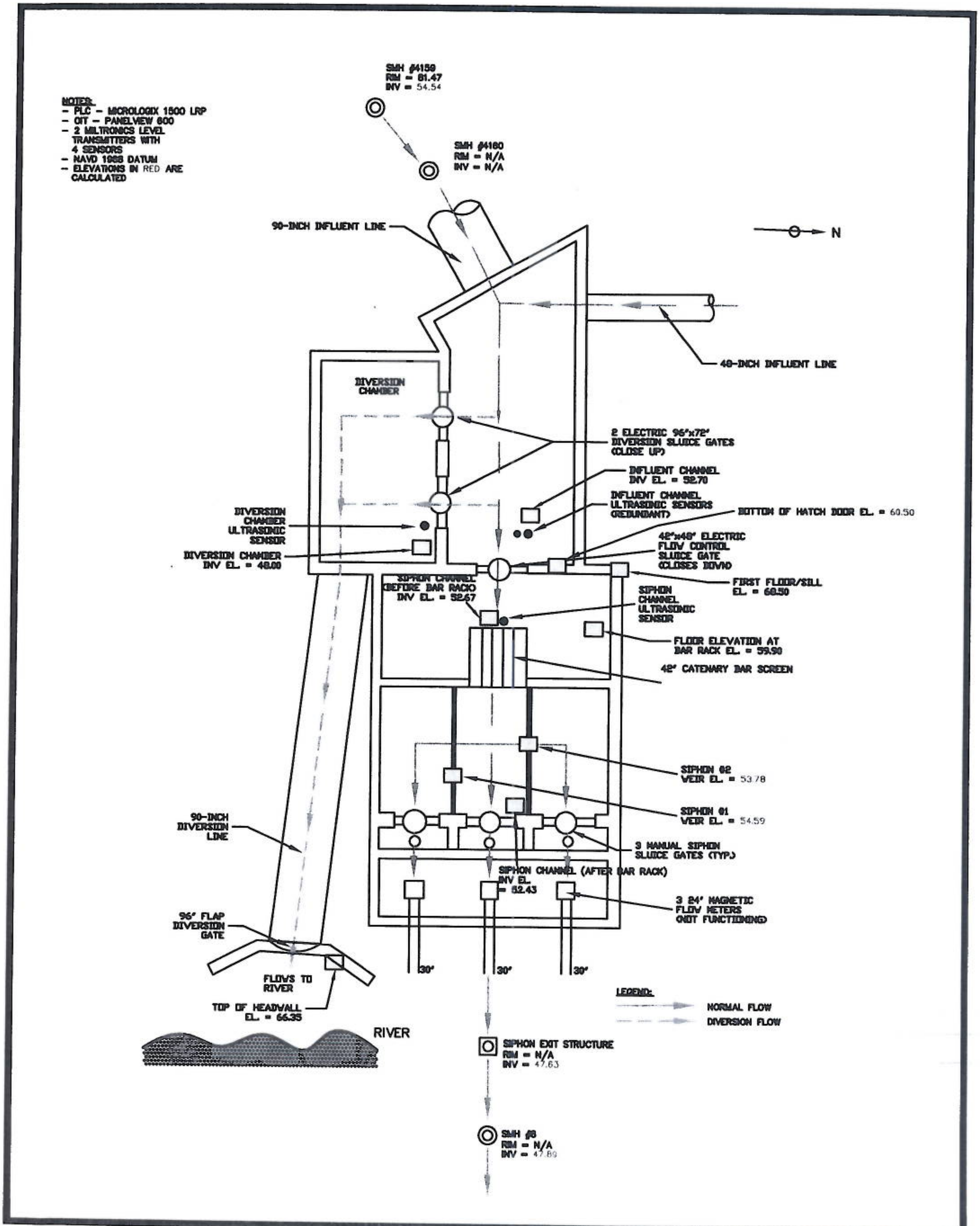
Dry weather flow from the Warren Interceptor and the Marginal Interceptor combines into an influent chamber. The flow typically proceeds through an influent control sluice gate into a channel in the below grade portion of the station and through a mechanically cleaned bar screen before the flow enters three siphons under the Concord River that connect to the Merrimack West Interceptor. The siphons have magnetic flow meters that are currently not functioning.


Warren CSO Station

There are two overflow sluice gates at the Warren Street Station, within the influent structure, which are activated automatically by an ultrasonic sensor (located in the influent chamber). The flow control gate on the influent channel is normally fully open and closes to limit flow past the bar screen based on channel depths. The flow control gate is utilized to maximize Warren Interceptor depths for inline storage. When wet weather flow exceeds the siphon capacity (determined by channel depth at the screen) and the upstream interceptor pipe storage capacity, the two diversion gates are opened to divert excess flow. Meanwhile flow through the siphon to the Duck Island WWTF is maximized during diversion operations.

The gravity diversion gates open down and function as variable weirs that are used to measure the CSO discharge from the facility. Flow is discharged to the Concord River via a 96 inch diameter outfall pipe with a flap gate to restrict river water from entering. High river depths do not typically restrict the gravity diversion capability of this station. There is no pumped discharge.

There are two depth monitoring devices in this station. An ultrasonic sensor is located within the influent channel (used to estimate diversion flow over the top of the gates and interceptor pipe storage depths) and another is located in the siphon channel before the bar screen to prevent overtopping of the interior conveyance channel in the station using the flow control gate.



CDM Smith

Figure No. 2-20
WARREN CSO STATION
NOVEMBER 2013

Barasford CSO Diversion Station

This station is a below-ground structure is located adjacent to the Merrimack CSO Diversion Station. Figure 2-21 shows a schematic drawing of the regulator station layout.

Dry weather flow from the Barasford Interceptor, from the Wentworth Avenue and Douglas Road area and the Belvidere neighborhood area, proceeds through a parshall flume and into the Merrimack East Interceptor. Diversions at this CSO structure are activated automatically when the diversion gate is opened based on Merrimack Interceptor water levels. The flow control and diversion gates are modulated together to maximize flow into the interceptor. As soon as the flow control gate starts to close, the diversion gate is opened (opens down and act as a variable depth weir). Although the CSO outfall pipe is equipped with a flap gate to restrict river water from entering the collection system; the outfall pipe is very high and typically can discharge CSOs during most river conditions. There is no pumped discharge at this station.

Barasford CSO Station

There is a parshall flume located along the dry weather connector pipe. There are two depth monitoring devices in this structure: one in the influent channel of the structure and one device in the outfall chamber (to measure activation and estimate CSO discharges)

Merrimack CSO Diversion Station

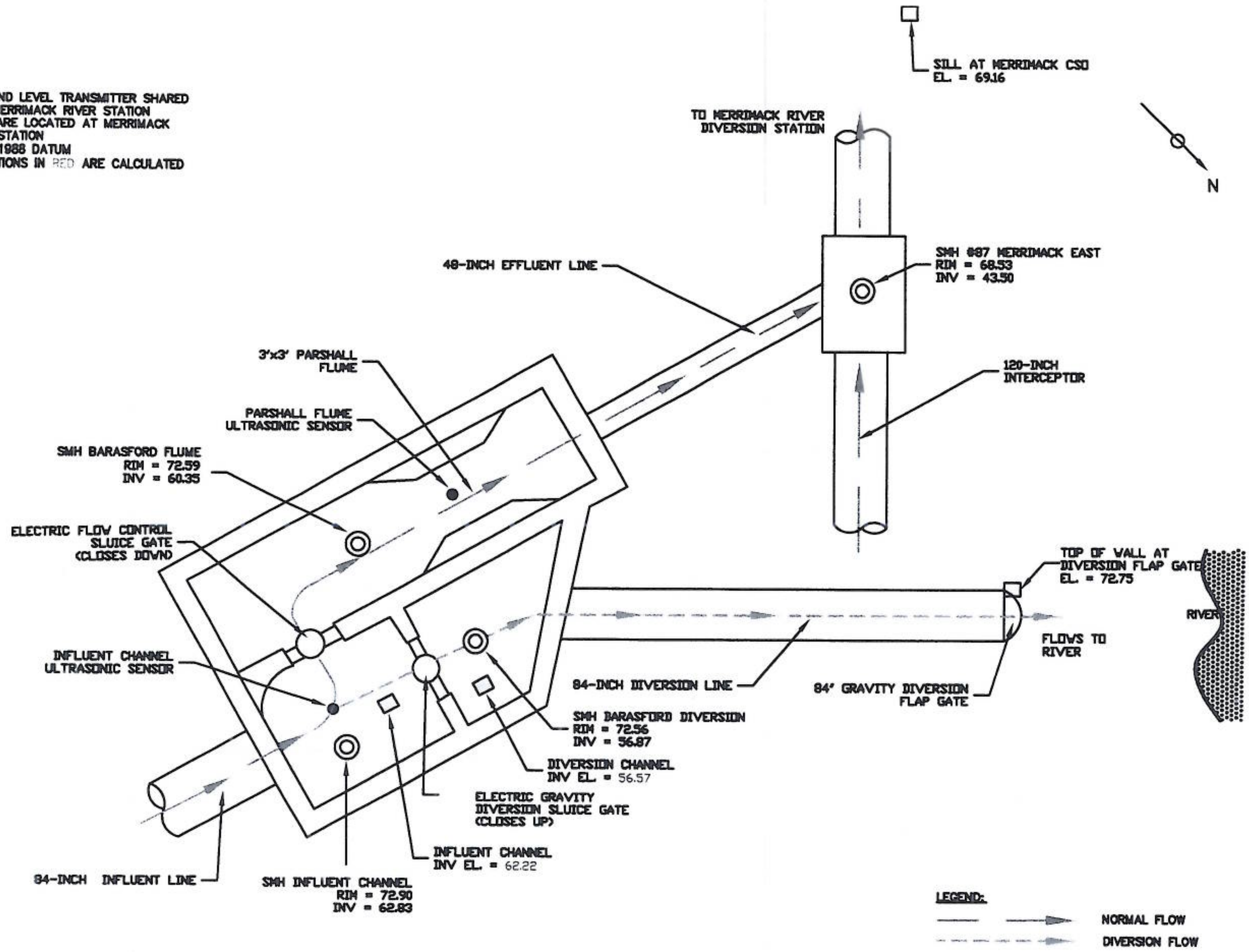
This facility includes both a building and below-ground levels and is located across the Merrimack River from the Duck Island WWTF. Figure 2-22 is a schematic drawing of the regulator station layout. This facility is the primary point of control for flows entering the Duck Island facility from the south bank interceptor system (via a set of siphons under the Merrimack River). Duck Island operators often manually (and remotely) control this station, along with the West CSO Station, to maximize flow to the WWTF based on river depths, storm conditions, WWTF flow rates, and interceptor storage levels.

Merrimack CSO Station

Typically dry weather flows enters the station from the Merrimack East and West Interceptors, proceeds through the flow control gate, then a mechanically cleaned bar rack and into the siphons under the river. The siphons have a capacity of about 63 MGD. Flow to the WWTF is controlled by modulating the flow control sluice gate located within the station. This gate is controlled both automatically by the local PLC and by the WWTF operators via SCADA.

NOTES:

- PLC AND LEVEL TRANSMITTER SHARED WITH MERRIMACK RIVER STATION BOTH ARE LOCATED AT MERRIMACK RIVER STATION
- NAVD 1988 DATUM
- ELEVATIONS IN RED ARE CALCULATED



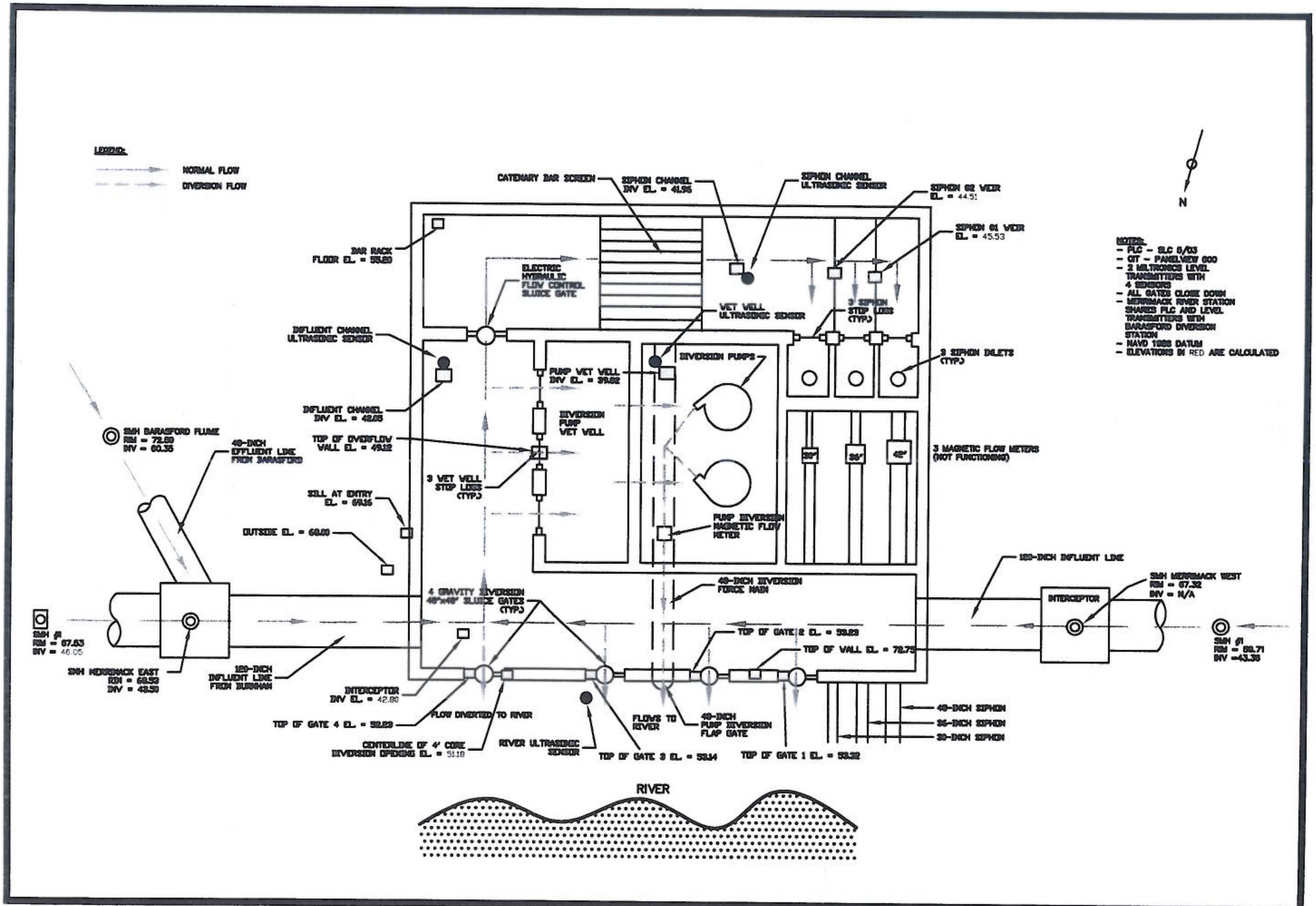
LEGEND:

NORMAL FLOW

DIVERSION FLOW

CDM Smith

Figure No. 2-21
BARASFORD CSO STATION
NOVEMBER 2013



CDM Smith

Figure No. 2-22
MERRIMACK CSO STATION
NOVEMBER 2013

CSOs are discharged to the Merrimack River via gravity diversion or pumped flow diversion (400 MGD capacity). Gravity CSO diversion occurs via four gravity diversion openings that are adjacent to the Merrimack Interceptor along the river wall. There is a sluice gate installed on each opening that is controlled by the local PLC. When flow depths in the Merrimack Interceptor rise towards the crown of the pipe, the gravity diversion gates are opened sequentially and incrementally. These diversion gates modulate along with the flow control gate at the Merrimack Station to maximize flow depth in the Merrimack Interceptor for inline storage, maximize flow to the WWTF, and minimize CSO discharges. There are no flap gates on the four gravity diversion openings; thus, when these gates are open, there is the potential for river water to enter the interceptor and the gravity diversion gates are not opened.

During high river levels, CSO discharges can be pumped into the river. The wet well to the pumping station is adjacent to the influent structure, but upstream of the modulating influent flow control gate. If the channel level rises to a certain elevation and the gravity gates aren't opened, flow enters the wet well through three openings. The wet well pumps are activated automatically based on wet well levels. The pumped flow diversion outfall pipes are equipped with a flap gate to restrict river water at high levels from entering the system.

There are two depth monitoring devices measure flow through this structure. One device is located in the influent channel (upstream of the flow control gate and is used to measure interceptor levels) and the other is located in the siphon channel (after the bar screen) to measure depth of flow over the control weirs to each of the siphons, which is used to measure flow to the WWTF. CSO gravity diversion flows are estimated using an orifice equation and interceptor depths. Flows into the pump wet well are estimated based on flow over a weir (bottom of the openings into the wet well) and verified, as practical, using the mag meter on the pump discharge line.

2.2.6 Dry Weather Overflows

There are no known dry weather overflows (DWO's) from Lowell's combined sewer system. LRWWU conducts regular inspections of the facilities and regulators during high and low groundwater seasons. No evidence of dry weather overflows have been observed during these inspections. If a dry weather overflow was noted during the inspections, the LRWWU would proceed immediately to identify and remove any obstructions in the pipe to eliminate the DWO.

All stations are also operated based on influent level sensors and the diversion gates (with the exception of Read CSO Station) are closed except during wet weather events. Thus, DWOs should not occur as these facilities. If DWOs were inadvertently created, there would be alarms from the depth meters in each of the facilities that would inform the WWTF operator.

2.2.7 Wet Weather Operations

Typically, five of the CSO stations - the Beaver Brook, Barasford, Merrimack, Tilden, West and Warren CSO Diversion Stations - are automatically activated to divert excess wet weather flow to the rivers. Overall system operation and activation of the CSO diversion stations during wet weather events is a complex series of decisions made by the local PLC, WWTF Operators based on river levels, incoming storm characteristics, time of day, and facility operations. The Walker and Read CSO Stations operate passively, based on depth over a weir, but have no remote gate operations. The First Street Station is not operated or monitored.

The SCADA system controls at the five CSO stations are primarily based on local control conditions with the first intent to convey as much flow downstream and to utilize inline storage, if possible. The controls are also adjusted automatically for downstream and WWTF flow/capacity conditions. LRWWU operates the system based on its High Flow Management Plan; this is discussed further in Section 3.

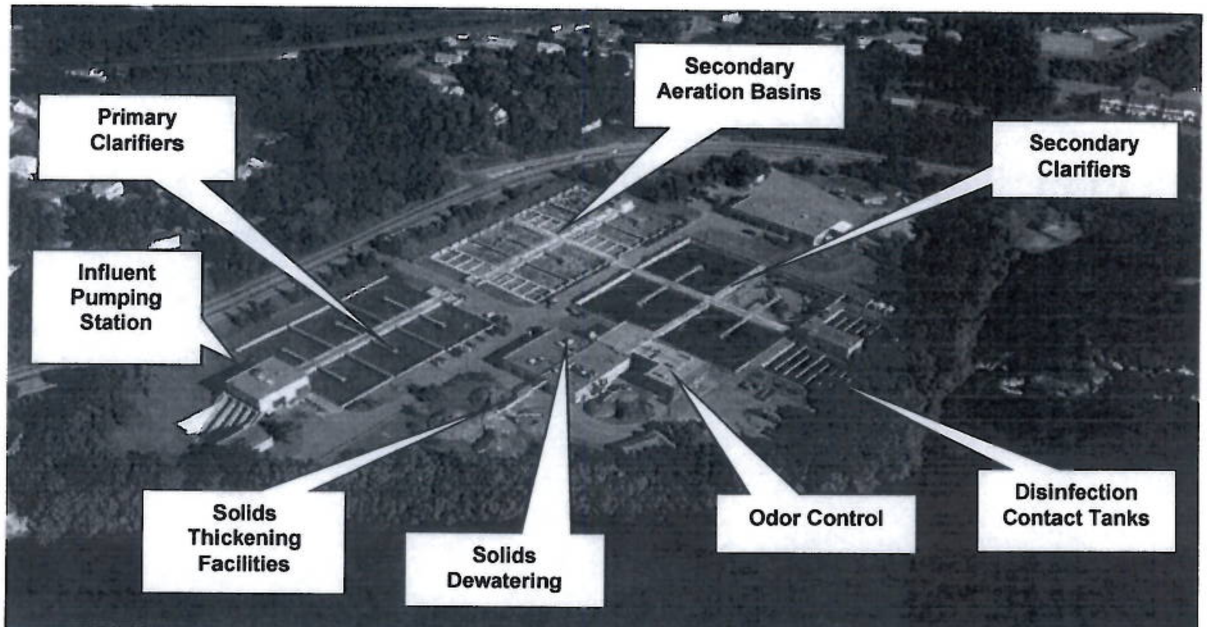
High river levels also affect operations at the Beaver Brook, Merrimack, Tilden, and West facilities. Beaver Brook, Merrimack and Tilden have pumps to discharge CSOs during high river levels. If there are high river levels at West that prohibit a gravity discharge, wet weather flow is diverted from the upstream Beaver Brook facility or from the Merrimack Station on the south bank. All of the pumped diversions are initiated automatically based wet well depths when flow is diverted into the wetwell.

2.3 Wastewater Treatment Facility

2.3.1 General

The Duck Island Regional Wastewater Treatment Facility is located along the Merrimack River adjacent to the Lowell/Dracut corporate boundary (formerly Duck Island). This WWTF became fully operational in 1980. The facility utilizes a conventional activated sludge secondary treatment process.

Average daily flows to the WWTF range from 22-30 MGD during the year, based on seasonal



Overview of Duck Island WWTF

groundwater conditions. There is limited growth projected in Lowell because there is only a small amount of land available for development in the city. Chelmsford, Dracut and Tewksbury were originally part of the regional compact when the WWTF was constructed. These communities discharge to the Lowell collection system and WWTF based on inter-municipal agreements with Lowell. Most of these communities are finishing with planned sewer expansion programs that will eventually match the flow limits established in the inter-municipal agreements. Tyngsboro is purchasing capacity from Dracut to discharge to the WWTF.

The current dry weather treatment capacity of the facility is adequate for the future projected flows. LRWWU has evaluated the overall facility capacity to determine if the facility could be rerated to accept additional future flows if required. By lowering effluent standards, the analyses showed that a capacity rerate could be justified. However, the additional treatment capacity is not necessary at this time, and LRWWU is also considering future NPDES effluent limitations for nutrients that may limit the eventual rerated capacity.

2.3.2 Treatment Process

Treatment of flow entering the facility consists of screening and primary sedimentation followed by activated sludge secondary treatment. Influent flow is pumped from the interceptor by four large diameter screw pumps, passes through two mechanical bar screens, and then is discharged into six tanks for primary sedimentations. Primary effluent is conveyed to the secondary treatment facility consisting of four activated sludge treatment trains (consisting of a series of basins for a selector—style approach to minimize filamentaeous growth and equipped with both mechanical mixers and diffused air distribution piping to provide flexible anoxic and aeration zones). There are four secondary clarifiers after the secondary aeration process. After secondary treatment, effluent flow is chlorinated and dechlorinated prior to discharge to the Merrimack River.

Primary solids are degritted and then thickened in gravity thickeners. Waste activated solids are thickened using rotary drum thickeners. Thickened primary and secondary solids are stored separately and then combined just prior to dewatering using centrifuges. Dewatered solids are hauled off-site for disposal.

The facility has a secondary bypass conduit that is utilized to maximize treatment capacity during wet weather (or snow melt) conditions to provide primary-only and disinfection to wet weather flow. When primary clarifier effluent exceeds the secondary treatment process capacity, the excess flow is diverted around the secondary treatment process using a bypass conduit. Flows are recombined prior to disinfection and dechloration.

The majority of the facility equipment was over 20 years old and starting to exceed its useful life. Over the last seven years, LRWWU has completed several phases of construction to rehabilitate its facilities including new influent pumping and screening; aeration process adjustments, aeration improvements and control system; secondary sludge valves; chlorination and dechlorination improvements; and a revamped solids train including new gravity thickeners for primary solids, rotary drum thickeners for secondary solids, and centrifuges for dewatering. In addition, LRWWU renovated its administration and maintenance spaces, and installed a new odor control system. This work is discussed in Section 3. Over the next decade, the LRWWU expects to continue to this infrastructure improvements program at the WWTF.

2.3.3 Treatment Capacity

Dry Weather

Lowell's WWTF was designed to provide secondary treatment for an average day wastewater flow of up to 32MGD, with a maximum day secondary treatment capacity of 52 MGD.

Currently, Lowell's influent dry weather flow rates are well below the 32 MGD design capacity, which has been reduced through recent system improvements including better flow monitoring throughout the facility, and an extensive I/I reduction program implemented in the collection system.

LRWWU will continue to rehabilitate the system on an annual basis to address the infiltration problem. Every year, the utility completes several pipe lining and repair projects to eliminate problem areas. To increase available capacity at the WWTF, the LRWWU plans to continue this effort to identify and reduce sources of infiltration.

Wet Weather

Lowell's WWTF is capable of providing treatment to wet weather flow in excess of its secondary treatment capacity of 52 MGD. Influent screw pumps, screens, conveyance channels, primary sedimentation and chlorination facilities at the plant were originally designed to provide primary treatment and disinfection up to about 110 MGD. During wet weather, (primary effluent) flows greater than the secondary treatment capacity (52 MGD) are conveyed around the secondary system (through a secondary bypass conduit) and recombined with secondary effluent prior to disinfection (and discharge) of the combined flow.

As noted above, LRWWU has completed a number of significant capital improvements projects to upgrade and revitalize the aging equipment and processes at the facility. These improvements have improved system processes, lowered maintenance costs, reduced electrical consumption, minimized odors, and improved the reliability of the facilities to maximize treatment capacity during wet weather events.

The plant is still not consistently treating up to its reported design capacity of 110 MGD during all storm events. Currently, wet weather operations at the WWTF are typically limited to an average of about 90 to 100 MGD, depending on preceding flow conditions and equipment failures. In the proposed CSO Phase 2 LTCP, LRWWU intends complete additional WWTF improvement to increase the effective wet weather treatment capacity and to determine the reliable treatment rate than can be consistently achieved at the plant for the future.

2.4 Pumping Stations

Lowell's wastewater collection system also includes twelve (12) pumping stations. Table 2-5 below summarizes the capacities of the pumping and ejector stations.

Table 2-5 Summary of LRWWU Pumping Stations

Station Name	Location of Station	Number of Pumps	Pump Capacity	Total Dynamic Head
Chelmsford	Chelmsford @ York Avenue	3	800 GPM each	50 ft.
Pawtucketville	Pawtucket Boulevard	3	1250 GPM each	50 ft.
Princeton	Princeton Street @ Hadley Street	2	1600 GPM each	88.5 ft.
Rosemont	Rosemont Street	2	400 GPM each	19 ft.
School Street	School Street	2	500 GPM each	20 ft.
Varnum	Varnum Avenue @ Laurie Lane	3	1400 GPM each	73 ft.

2.5 Stormwater Drainage System

2.5.1 General

Approximately 44 percent of the sewered area in Lowell is served by a separate sanitary collection system. Storm water drainage in these areas is collected by a drainage piping system and/or directly discharges to watercourses and manmade open channels. There are approximately 54 miles of drain pipe in the LRWWU. Figure 2-23 shows the locations of the existing drain pipes and outfalls based on the city's GIS.

Separate stormwater drainage systems are predominately located in the western and southeastern portions of the LRWWU. New drainage pipe, however, has been installed in central Lowell with urban renewal and street reconstruction projects. Where an appropriate outfall could be readily constructed, drainage flows are conveyed to a receiving water/wetland. In the past, where this could not be accomplished, stormwater drainage systems were reconnected to the combined sewer system.

Lowell's stormwater drainage system is permitted under the General NPDES Phase II Stormwater Permit issued in 2003. The permit requires Lowell to perform six minimum control measures (NMCs), which are best management practices, and provide annual reports on the progress of the NMC. The stormwater system is jointly administered and operated by the Lowell Department of Public Works, City Engineering, and LRWWU.

2.5.2 System Inspections

A full inventory of all stormwater outfalls was completed in 2004 for the Phase II Stormwater Permit. At this time, the outfalls were inspected and documented. During the field investigations, drainage outfalls with dry weather flow were sampled to determine if there were any illicit sewer connections. LRWWU followed up and removed all identified illicit connections at the time. LRWWU continues to follow-up on outfall inspections and dry-weather sampling as part of the NPDES program. When the dry weather sampling has indicated the potential presence of illicit connections, LRWWU staff has completed investigations to identify the illicit connection location and the illicit connections are removed by LRWWU.

LRWWU continues to update its GIS database of the drainage system based on field investigations and daily work.

2.5.3 Partially Separated Areas

In some areas of the combined sewer system, new drains have been installed in streets, but were eventually connected to the existing combined system if there was no nearby receiving water body. For the most part, this partial separation condition has occurred with new developments where the Sewer Use Ordinance required a separated system, but it was cost prohibitive for the develop to extend the drain to an existing separated drainage channel.

In other areas of the system, there are two pipes in the street for separate drainage and sewer, but there may be random catch basins still connected to the sanitary sewer. In these areas, sump pumps and roof leaders from buildings may also be connected to the sanitary system through sewer services.

LRWWU continues to work on eliminating, to the extent possible, incorrectly connected catch basins as they are identified in the field. This work ranges from simple reconnections of the existing catch basin to the nearby drain to the installation of short lengths of new drain pipe to connect a street to an existing drain. LRWWU intends to continue an annual program to eliminate these random connections and complete separation in the areas with existing storm drains.

2.5.4 Non-Rain Related Inflow Sources: Brooks/Streams

There are several locations in Lowell where extraneous surface inflow from brooks and wetlands enters the combined sewer system. These flows are more continuous than just direct runoff from rain events. Drainage from these areas was piped into the collection system as the Lowell developed. There are no nearby receiving streams and city officials at the time decided that a connection to the sewer system was necessary to avoid the potential flooding that could occur if the discharge from these areas was not relieved. These flows are ultimately conveyed to the WWTF and reduce dry weather treatment capacity and available wet weather treatment capacity during rainfall events.

Extraneous inflow sources that were readily identified in Lowell include:

Humphrey's Brook

Humphrey's Brook just before it enters the collection system

This brook drains a large area of approximately 374 acres that extends northeast of Humphrey Street. A large portion of the tributary area to this brook is located in Dracut. Inflow enters the sewer system at Humphrey Street through a 48-inch diameter pipe connection to a manhole that is approximately 225 feet south of the intersection of Humphrey Street and Pemberton Street. Typically dry weather flows from this area can range anywhere from about 0 MGD in summertime to as much as 1 MGD in the springtime, with average flow rates of about 0.2 MGD to 0.8 MGD during dry weather conditions based on flow monitoring performed by LRWWU in 2007 and 2008). Flow rates can be more than 15 MGD during more significant rain events. During springtime conditions, the low lying area adjacent to the brook, just upstream of the 48-inch inlet, floods. Flooding in this area creates more inflow since an existing sewer line traverses the area and high brook water levels exceed the elevation of manhole covers.

A separation pipe plan for this area was developed in the Humphreys Brook Area Combined Sewer Separation Project Preliminary Design Report (CDM, 2000). The pipe would have to extend from the Dracut border to the Merrimack River; a distance of about 1.5 miles. The cost for separation of this brook flow is significant at about $15 million (2014 dollars) and a downstream solution would be required to discharge the drainage flow into the Merrimack River during high river levels (due to the low lying areas behind the Lakeview levee. The West Street Flood Control pumping station is inoperable and can't be used to discharge the excess stormwater flow. Accordingly, either a new stormwater pumping station would have to be constructed at additional cost or the new pipeline would have to function as a pressure flow conveyance conduit (with no stormwater connections in the low lying areas) to discharge brook flow from the upstream areas into the river under flood conditions.

In the early 2000s, LRWWU was considering this brook separation plan as an option to reduce dry weather flow rates at the WWTF but an alternative at the WWTF was identified that was less costly, especially considering that the brook separation plan would cost $15 million to alleviate the higher springtime flows that were only a short term condition.

The impact of the brook flow on CSO discharges was considered less significant as flows from the impervious areas in the West Station drainage basin in Lowell contribute peak flows in excess of 200 MGD. The brook flow impact is lower because of its distance from the station and the resulting time of concentration of the peak flow from the entire CSO tributary area.

Billings Street

There is a low lying area and seasonal pond along Billings Street that has a tributary area confined by Bridge Street/Route 38, Barker Avenue, and Aiken Avenue. The tributary area is estimated to be about 51 acres. Flow enters the system at a manhole that is approximately 300 feet due west from the intersection of Billing Street and Bridge Street. 2007/2008 flow monitoring indicated that this area contributed about 0.02 MGD under most conditions, except in spring and during rain events. Springtime flows during dry weather conditions could be as high as 0.3 MGD on average and as high as 0.9 MGD during a rain event. This area was included in the separation plan for the Humphreys Brook Area Combined Sewer Separation Project Preliminary Design Report (CDM, 2000).

Billing Street Wetlands

Hovey Field

Hovey Field has a surface drainage system that conveys flows to a head wall located just south of the LRWWU line with Dracut. This pipe passes through a ball field (Hovey Field) and connects to the combined sewer system along Hildreth Street approximately 450 feet southeast of the intersection with Orleans Street. This pipe connects to the combined sewer system as a manhole located along an 18-inch x 27-inch brick system.

2007/2008 flow monitoring indicated that average dry weather flows ranged from about 0 MGD to 0.5 MGD. Wet weather flow peaks from this area were more significant ranging up to 5 MGD during a thunderstorm in the summer of 2008.

Mansur Street

This area contributes seasonal discharge from a pond and tributary area confined by Wentworth Avenue to the east and Starr Avenue to the west. A culvert under Hovey Street (to the south) conveys flows from the extremity of the catchment area, approximately 1,300 feet from the point of connection to the sewer system. Flow from the ponded area enters a 15-inch diameter pipe connection to a manhole that is approximately 250 feet due west of the intersection of Mansur Street and Wentworth Avenue. There is no nearby drainage system to relieve this flow from the sewer system.

Ottawa Street

The 1990 Phase I/I report noted that there is a 6-inch connection to a manhole at the end of Ottawa Street. This 6-inch pipe connection serves a surface drain for a small area at the end of the street. There is no opportunity to drain this pipe into Beaver Brook as it is behind the flood protection levee.

Other Inflow Sources

In addition to the inflow sources discussed above there are other closed pipe drainage systems such as at the McPherson Playground and the Robinson Middle School that also connect to the combined sewer system.

2.6 System Issues and Planning Considerations

During the development of the LTCP Update, LRWWU identified a couple of system issues and planning considerations that should be incorporated into the LTCP program.

2.6.1 East Merrimack Siphon Station

The East Merrimack Siphon Station is located along East Merrimack Street on the west side of the Concord River. This station is the inlet structure for a set of siphons that convey flow from a small downtown area of Lowell under the Concord River and into the Merrimack West Interceptor, just downstream of the Warren CSO Station connection. The station includes above- and below-ground facilities and used to have an operating bar screen that was used to remove solids before the flow went into the siphons. The above grade portion of the station included ventilation equipment for the below grade structure. The station has fallen into disrepair.

Recently, LRWWU removed the bar screens and has operated the siphons without the solids protection with no reported problems. In the long-term, the city would like to modify the station and remove the above-grade facilities.

2.6.2 Marginal/Middlesex Interceptor

In the early 1980s, after the city closed the Pevey Street and Thorndike Street CSO regulator/outfalls along the Marginal/Middlesex Interceptor, the interceptor began to experience excessive surcharge. The existing interceptor was originally designed with larger diameter pipes entering the CSO regulator structures and exiting into smaller diameter pipes. Now, the higher upstream flows have no relief being conveyed by the smaller downstream pipes at the two locations of the former CSO outfalls.

The surcharging has resulted in sewer backups and surfacing flooding issues upstream of the intersection of Middlesex Street and Branch Street where a 45-inch x 30-inch brick trunk sewer from Highland neighborhood combines with the Marginal Interceptor (42-inch x 23-inch brick) and the combined flow is conveyed by a 52- inch x 35-inch brick sewer east towards Warren CSO Station. This area has a mix of commercial, residential, and public property. The sewer ranges in size from a 36-inch reinforced concrete pipe to a 42-inch x 23-inch brick pipe in this area. Portions of the interceptor run directly underneath a number of large commercial buildings.

Notable issues include street flooding and basement backups at the Boys and Girls Club (647 Middlesex Street), sewer backups at the UMass Lowell Riverview Campus Dormitory (141 Marginal Street), and surface flooding within and in front of the Department of Public Works Building (1361

Middlesex Street). These events typically have occurred at storm events greater than a 1 year storm event. To relieve surcharging in the area, LRWWU installed a cross connection at the upstream end of the Marginal Interceptor that allows surcharged flow to backflow into the Walker CSO Station tributary area. In addition, significant maintenance of the interceptor system by LRWWU has helped to minimize more recent surcharging but the issues still remain. However, additional relief is still required. LRWWU considers improvements to reduce the surcharging issue within this sewer area to be a top priority as part of its system improvements program. This issue and potential solutions are discussed further in Section 6.

2.6.3 Wentworth Avenue and Douglas Road Area

The Wentworth Avenue and Douglas Road areas have both combined sewer and sanitary sewer systems that drain to the Barasford Interceptor and the Barasford CSO Station. As noted above, this area is separated from the Merrimack River by a topographic divide and the natural drainage is into Trull Brook, which flows to the east into Tewksbury.

The upstream drainage area associated with this area is about 500 acres, of which about 20 percent is served by separated sanitary sewer systems and the remaining area is served by the combined sewer system. The separated storm drains convey flow into an open channel/wetland body and culverted drainage system that eventually connects to Trull Brook, via a drain installed parallel to Douglas Road. Past assessments of the pipelines in the area showed that both the combined sewer system and the parallel drainage systems have capacity deficiencies for the projected design storm flow rates.

Excessive combined sewer flow results in surcharges at Wentworth Avenue (east of Rogers Street) and along Douglas Road (near Cauley Stadium). Excessive stormwater flows cause surcharge in the Phoenix Avenue wetlands (which back up into Wentworth Avenue), along the Douglas Road drain, and at the Clarks Road wetland (which backs up into Alcott Avenue). Previous assessments indicated some sediment in the drainage system and some beaver-created blockage in the wetlands that were reducing drainage flow capacity. LRWWU has rectified these problems, which has reduced the occurrence of flooding, but the flooding still remains during significant storm events. Solutions to the surcharge problems in this area are discussed further in Section 7.

Section 3

Phase I LTCP Progress

3.1 General

LRWWU initiated its Phase I LTCP implementation plan in early 2000 before the Revised Draft LTCP Report was completed in 2002. Since that time, the LRWWU has implemented an aggressive phased program to reduces its CSO discharges and repair its aging system based on an adaptive management approach. LRWWU has spent $120 million on planning, design, and construction of WWTF capacity and reliability improvements, interceptor optimization, improvements to and comprehensive instrumentation and controls installed at the CSO diversion stations, sewer separation, infiltration/inflow reduction programs, and implementation of a sophisticated High Flow Management Plan aimed at reducing CSO discharges from the Lowell combined sewer system. Concurrently, LRWWU has kept up with other NPDES compliance requirements including the NPDES stormwater compliance and CMOM programs. Table 3-1 summarizes LRWWU's Phase 1 program.

Implementing an adaptive management approach, LRWWU constantly reassesses its capital improvements program to ensure that cost-effective programs and approaches are utilized to reduce CSOs and to revitalize the collection system infrastructure. There have been many successes and this has led to continued support at City Hall and by the public for a continued, targeted, and reasonable spending plan to comply with the state water quality standards.

LRWWU also initiated a comprehensive assessment of all of its facilities to develop an integrated capital improvement plan that incorporated equipment renewals (to retrofit its aging infrastructure), improve treatment processes, maximize the use of instrumentation and control technology to make real-time facility decisions, and to documents its assets for future planning and capital improvements. This work has established an important framework as LRWWU continues to improve its collection and treatment facilities for the next century of operations.

This section provides a summary of the capital spending, planning programs, and compliance activities that LRWWU has undertaken over the last 12 years since the Phase I LTCP program was first approved by the agencies and initiated by LRWWU.

3.2 Nine Minimum Control Measures

Nine minimum controls (NMC) for combined sewer systems as described in EPA Guidance Manual No. 832-B-95-003 are controls that can reduce CSOs and their effects on receiving water quality without requiring significant engineering studies or major construction and can be implemented in a short period of time. The city's NPDES permit requires the implementation of the NMCs as a first step to controlling CSO discharges. Since 1990, the city has implemented all aspects of the nine minimum control strategies as discussed below. LRWWU submits annual reports on the performance of their NMC program as part of the NPDES permit.

TABLE 3-1
LRWWU LTCP / CIP PROGRAM SUMMARY

Program	Project	Project Cost	Project Description	Project Completion
CIP Phase 1A	Emergency WWTF Upgrades	$5 M	• Gravity Thickener & Aeration Blower Upgrades • CIP Engineering Design	2008
CSO Phase 1 LTCP	Wet Weather Operations & Sewer Separation	$90 M	• WWTF Wet Weather Treatment Capacity • Diversion Station Control & Interceptor Storage • Sewer Separation Program • Infiltration / Inflow Reduction • Sewer Rehabilitation Program • Sump Pump Disconnection Program (ARRA) • WWTF Influent Pumping Station • Warren CSO Diversion Station • Interceptor System Storage	2011
CIP Phase 1B-01/02	Odor Control Process Improvements High Flow Management Flood Protection	$23 M	• Solids & Septage Upgrade • Odor Control & Site Improvements • HVAC, Electrical & Mechanical Systems • WWTF Aeration System Upgrade (ARRA) • Green Roofs & Photovoltaic (ARRA) • Flood Protection System – Levee Stabilization	2012
CIP Phase 1B-03	WWTF Upgrades	$2 M	• WWTF SCADA & Electrical Upgrades • Hauled Waste Storage Facilities • Process Control Improvements	2013
Phase 1 Subtotal	2003 – 2013	$120 M	CIP/LTCP Phase 1 ($8.4M in ARRA Funding)	2013

Proper operation and regular maintenance programs for the sewer system and CSO outfalls

Since 1990, the city has implemented a vigorous operation and maintenance program on their combined sewer system including regular inspection and cleaning of all gravity sewers, drains, pumping stations, 9 CSO diversion stations and outfalls. The city has trained, dedicated staff that work year round inspecting the diversion and pumping stations, cleaning catch basins, jetting and rodding sewer and drains, TV inspection of sewers, cleaning and maintaining pumping stations and wet wells. The city has its own fleet of TV inspection and pipe cleaning equipment.

LRWWU tracks its progress on system maintenance using a data management and reporting software and is considering the development within the next several years of a more enhanced computerized maintenance management system for work orders and recordkeeping to monitor preventive maintenance and inspection procedures and to track asset repair, replacement, and rehabilitation costs.

LRWWU maintains a sophisticated geographic information system (GIS) that includes all of the significant pipe information for both sewer and stormwater systems, including sewer laterals. The GIS is maintained annually to update it for any known corrections to the database and/or changes or updates the city makes as part of the capital improvements plan. Field staff also have laptop computers in the field to access the database and to record corrections that are observed in the field.

LRWWU also completed improvement projects at several of the CSO diversion stations to improve operations, to monitor control valves (to minimize CSO discharges, and to improve worker safety. LRWWU also replaced the School Street Pumping Station to improve operations and minimize maintenance and LRWWU is evaluating other capital improvements to allow remote monitoring of key sewer pumping stations and completely rehabilitation of the stations to improve maintenance.

Maximize the use of the collection system for storage

LRWWU has a very advanced real-time control system to allow the utility to maximize the use of the large diameter interceptor system for storage of wet weather flow to minimize CSO discharges. The control system required several phases of work to install new flow control valves at most of the CSO diversion stations, new depth monitoring devices, and a very extensive supervisory control and data acquisition system (SCADA) to collect the monitoring data, to control gates in the system, and to maximize the use of treatment at the WWTF and storage within the combined sewer system.

Installing the equipment was one step in the process of maximizing storage in the system. LRWWU also utilized a workshop approach, using consultants and staff, to systematically evaluate separate storm events on a periodic basis to examine the impacts in the system, estimate the amount of CSO discharge, identify the operational parameters when a discharge occurred, and provide suggestions on what system operational changes could be made to further maximize control in the system. Ultimately, this collaborative effort helped LRWWU to gain a much better understanding of how the system responds to storm events and to capture wet weather without resulting in catastrophic system flooding.

Review and modification of pretreatment requirements to ensure the CSO impacts are minimized

The purpose of this control is to minimize impacts of discharges in the combined sewer system from non- domestic sources during wet weather events. LRWWU has implemented an industrial pretreatment program (IPP). All industrial discharges to the city's sewer system are required to adhere to the requirements of the city's IPP program. LRWWU consistently assesses the effluent quality of non-domestic discharges and adjusts the IPP program accordingly to minimize industrial pollution in its flow stream. When possible, LRWWU has encouraged the direct discharge of industrial flows into the process stream directly at the Duck Island WWTF to avoid the potential discharge of contaminants at the CSO discharges.

Maximization of flow to the publicly owned treatment works (POTW) for treatment

The fourth minimum control is focused on minimal modifications to the collection system and WWTF to enable as much wet weather flow as possible to reach the treatment facility with the ultimate goal of reducing the magnitude, frequency and duration of CSOs to receiving waters.

As discussed above, LRWWU has implemented many measures to maximize flow to the WWTF, including real time control, instrumentation and monitoring, and gate improvements, etc. and improving maintenance and operation of the system in general. In addition, as discussed further later in this section, LRWWU is currently implementing a capital improvements plan at the WWTF to renew existing equipment and enhance treatment processes at the facility to ensure reliable, and consistent, treatment to meet effluent quality standards.

Elimination of overflows during dry weather

Overflows from the CSO discharge outfalls are prohibited under the NPDES WWTF permit. LRWWU has a comprehensive depth monitoring system at most of the CSO regulator/outfalls to ensure that there are no dry weather overflows (DWOs). There are gravity diversion control gates at most of the CSO outfalls that remain closed during dry weather conditions to prevent DWOs. In addition, flow depths are monitored so that an alarm will be triggered with high depths of flow in the main interceptor that might overtop a weir (with the diversion gates closed). If flow were to enter wet wells and engage the CSO pumps, alarms would also be raised. LRWWU immediately investigates any alarms and to identify if any discharge alarms were triggered during dry weather flow conditions.

There have been no dry weather discharges from Lowell's combined sewer system.

Control of solid material and floatable material in CSOs:

Under this minimum control, visible floatables and solids should be controlled from being discharged to local receiving waters in the CSOs. The minimum control required communities to identify low-cost, easily implementable, actions that could reduce or eliminate floatables in the CSO discharges. Flow is screened at two of the nine CSO diversion stations (Beaver and Walker Stations) before it is potentially discharged to the river.

At the other sites, potential facility improvements were considered in the 1998 NMC report to help reduce the extent of potential floatables in the CSOs. Based on the past assessment, there are no easy and cost-effective approaches to capturing solids and floatable at the remaining stations for a variety of reasons including the constrained space within the CSO stations to install new screens, trash racks, or baffles, the lack of available land (most of the outfalls are situated directly on the river with no reasonable room for inline screens along the outfall pipe), and river/flow conditions that would preclude outfall technologies (like booms or netting systems).

Accordingly, LRWWU relies on devices such as catch basin hoods and (appropriately sized) sumps within catch basins, and other devices can be used to trap solids within the combined collection system. Lowell's major pollution prevention measure for the reduction of floatables to its receiving waters is the regular cleaning of catch basins and street sweeping.

Street sweeping is performed by the Lowell Department of Public Works and most streets are swept at least twice per year with the downtown streets being swept multiple times in the year. Catch basin cleaning is performed by outside contractors, funded by LRWWU. Lowell's catch basins are cleaned on a frequency of about once every ten years.

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Pollution prevention programs to reduce contaminants in CSOs

LRWWU and the city distribute brochures to maintain awareness of the stormwater and CSO pollution issues and CSO abatement requirements. As LRWWU has implemented its sewer separation program, public outreach has been utilized to inform local residents of pollution prevention issues.

LRWWU has a catch basin identification program that engages neighborhood associations to participate in the installation of plaques at catch basins that inform the public about the discharge destination of the stormwater flow. LRWWU maintains an annual program to coordinate with groups to continue to label the catch basins until all catch basins are properly labeled. This program educates the public about the effects of illicit dumping (into catch basins) and promotes stewardship of the public drainage system.

Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts

The purpose of this NMC is to inform the public of the location of CSO outfalls, the actual occurrence of CSOs, the possible health and environmental effects of CSOs and the curtailing of recreational activities due to CSO discharges. Each of the CSO stations and outfalls has signage that identifies the CSO outfall. Immediate notifications are also distributed to concerned parties downstream of Lowell whenever any CSO is discharged. Estimates of CSO flow discharges and the time period are also included in the notification.

LRWWU is developing a website to help keep the public informed about LRWWU and its progress on the CSO abatement program.

Monitoring to effectively characterize CSO impacts and the efficiency of CSO controls

LRWWU maintains an extensive network of depth and flow measurement gauges at the CSO diversion stations to monitor the activation of CSOs and to estimate CSO flow rates and volumes. LRWWU has spent an extensive amount of time, using temporary gauges, to confirm the flow measurements and volumes (estimated by using orifice flow equations or depth over a weir). While all flow measurements in turbulent conditions have inherent accuracy issues, LRWWU has worked diligently to apply the best flow measurement technology to obtain accurate CSO discharge measurements at each of the CSO Stations.

3.3 Capital Improvements Planning

In 2007, LRWWU initiated a comprehensive assessment of its infrastructure to develop a capital improvement plan (CIP) to revitalize aging facilities and equipment and identify opportunities to improve processes for the future. The work was completed using engineering consultants and staff at a cost of about $1.2 million.

This assessment includes a review all assets of the utility including the Duck Island WWTF and processes, sewer and drainage collection system piping, sewer pumping stations, revenue billing meters, and CSO diversion stations. This effort culminated in approximately a $340 million capital investments plan that has been implemented by LRWWU in a phased approach. Approximately $80 million of the original plan has already been completed.

LRWWU periodically assesses the priority of projects on the plan, adjusting the scope, budgets, and timing of the projects based on the ongoing needs and the benefits achieved for preceding projects. LRWWU is committed to continuing with the CIP to ensure that the federal and state permits and operations requirements are met, environmental impacts are reduced, and that the public and utility staff are safe with respect to wastewater facilities.

WWTF improvements remaining include projects that will replace the remaining aging equipment at the facility that was not already replaced in the latest phases of capital improvements (discussed later in this section), such as sludge dewatering equipment and the collector/scum equipment and solids pumps in the primary and secondary clarifier tanks, and capital improvements such as those related to the effluent pumping station and outfall, continued improvements to the electrical system throughout the plant, and potentially odor control in the future. The utility is also planning for a potential project related to sustainable energy/co-generation at the plan and has included an allowance for facility improvement that might be necessary to meet future restrictive effluent permit requirements. These WWTF improvements total about $87 million.

New Permit Limits

In the collection system, LRWWU's primary project is to complete a set of limited improvements to some key sewer pumping station - to replace existing pumps, consider different screenings handlings, and improve instrumentation for potential remote operation at each station to improve maintenance and increase reliability. LRWWU also prepared a budget for a program to inspect, clean, and maintain the interceptor system, especially the siphons. In addition, the utility is including capital costs to rehabilitate or replace each of its ewer pumping stations as over time they exceed their useful lifespan. Finally, LRWWU is including the eventual replacement of the revenue meters, flow meters, at each of the locations where LRWWU receives flow from the outside communities. The collection system renewal program is about $34 million.

3.4 LTCP Improvements

In 2005, LRWWU proposed to proceed with a CSO reduction plan that incorporated sewer separation of portions of the combined sewer area, improvements to diversion stations to allow in-line storage and interceptor optimization, WWTF improvements at Duck Island to increase wet weather treatment capacity, development of an active high flow management program using an comprehensive SCADA system, and sewer rehabilitation/replacement, along with inflow removal, to reduce extraneous flow in the system.

3.4.1 Sewer Separation and Inflow Removal

Table 3-2 summarizes the extent of sewer separation that has been completed by LRWWU in multiple construction contracts as a total of $58 million over from 2002 to 2012. A total of about 1,050 acres were separated by LRWWU, which represents a 20 percent reduction of the combined sewer area existing in 2005. The separation program included extensive system improvements including 80,700 feet (15 miles) of new drain, and about 46,000 linear feet (8.7 miles) of existing sewer that was either rehabilitated by CIPP lining or replacement entirely (due to adverse pipe conditions). Rehabilitation of the sewer system updated about 10 percent of the existing sewers and about 20 percent of the pipes older than 50 years old.

During the program, more than 2,200 property investigations were completed in the sewer separation areas. As new drains were installed, LRWWU disconnected existing drain connections to the sewer system and provided sump pumps to property owners directly connected to the sewer system. This avoided systemic problems with some property owners draining basements of groundwater by opening sewer cleanouts that were at floor level. LRWWU tried several approaches to inflow removal, including "splash" solutions outside the home, to balance the costs of inflow removal with a more permanent solution. Eventually, LRWWU adopted a practice to connect sump pumps, roof leaders, and yard drains to the sewer, to the extent possible, to avoid future sewer reconnections. This extensive sewer inflow removal program has increased the effectiveness of the sewer separation program system-wide.

The first two projects, Varnum/Laplume/West Meadow Street and Sixth and Emery were completed in the drainage area tributary to the Beaver CSO Station. Two new drainage outfalls were installed for these projects. Private properties were investigated during these program based on house-to-house surveys that were distributed to buildings. Eight sump pumps were removed in the program. Table 2-2 summarizes the approximate extraneous flow removed during this program from both sump pump removals and pipe rehabilitation/replacement. In the Sixth and Emery project, one building roof connections from a private school and six UMass Lowell building and three UMass Lowell parking lots were disconnected from the sewer system. The inflow removed from these sources was not included in Table 3-2.

The next three projects (Weed/Wellman/Lincoln West Parts I and II/Gorham South and Sewer Areas 24/25) were completed in the drainage area tributary to the Warren CSO Station. These projects resulted in a significant reduction in the overall combined sewer area, comprehensive sewer rehabilitation, and finished inflow removal and sewer rehabilitation in a partially separated area (Sewer Areas 24/25). Two new large diameter drain outfalls were installed as part of this project. During these projects, the city formulated a more aggressive inflow removal program targeted to removing the home owner practice of draining groundwater in basements into the sewer. This yielded many more property inspections and the installation of a significant amount of sump pumps and roof leader redirections. Table 3-2 shows the estimated inflow removed based on the number of sump pumps installed in this area.

The last sewer separation project was completed in two separate areas. The Cabot Street portion of the project separated about 70 acres in the Tilden CSO Station drainage area. This work included separation of several more UMass Lowell and private building roof connections. There were no sump pumps in this area to be removed from the sewer system. The Third and Ellis portion of the project was completed in the Beaver CSO Station drainage area. This completed separation of a partially separated area of about 80 acres. No inflow sources were identified in this area.

Overall, the sewer separation program resulted in the removal of a significant volume of public inflow from the city's catch basins and private inflow from roof leaders, yard drains, private catch basins, and sump pumps, along with infiltration that was removed with the comprehensive sewer system rehabilitation program.

3.4.2 Duck Island WWTF Improvements

The Duck Island WWTF facility was originally constructed in the late 1970s, more than 40 years ago and much of is equipment was aging to the point that maintenance costs and problematic operation were vastly outweighing the cost of comprehensive rehabilitation. Accordingly, LRWWU initiated the evaluation of existing infrastructure and development of its capital improvements program (discussed above).

Table 3-3 summarizes the various design and construction projects that have been completed to update the Duck Island facilities. To-date, about $43 million has been spent on upgrading the process and the facilities, all targeted to increase the dependability of operations, especially during wet weather conditions. Some of the largest projects undertaken at the WWTF were focused on rehabilitating critical processes/equipment to maximize wet weather treatment capacity to reduce CSO discharges. The improvements process has been comprehensive, based on the CIP, to address odors issues at the plant, provide dependable influent pumping and dependable power supply and electrical distribution, install dependable solids handling, and to enhance the secondary treatment (aerated sludge) process. There are several process areas of the plant that still require upgrading and these are presented in the CIP (Section 3.3) and include critical areas like the installation of permanent centrifuges, the rehabilitation of the primary and secondary clarifiers and solids handling equipment, final electrical distribution upgrades, and rehabilitation of the finished water pumps and effluent/diffuser pipe, and other less critical areas, like tunnel ventilation, continued SCADA/instrumentation improvements, maintenance management system deployment, and general housekeeping to remove abandoned equipment throughout the plant.

The USEPA has suggested that future NPDES permit renewals may decrease the effluent permit limits to achieve some level of nutrient or metals removal. This future effluent permit condition will require significant study and cost improvements to enhance a treatment process on a very tight site.

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Table 3-3
Summary of Duck Island WWTF Improvements

Construction Contract	Approximate Dates	Process/Equipment Addressed	Approximate Project Cost
Aeration System Upgrades	2000-2003	• Aeration System Improvements • RAS/WAS Pump System • RAS/WAS Lines • Disinfection System Replacement	$6.5 million
Beaver Brook/Read/WWTP Grit Modifications	2003-2005	• Primary Clarifier Solids Grit Removal System Replacement	$1.0 million
Gravity Thickener Upgrades	2007-2008	• Two GT Rehabilitated	$1.8 million
Contract 1B-01	2008-2011	• Odor Control System Rehabilitation • WWTF Plant-Wide Power Supply and Electrical System Upgrades • Septage Receiving Improvements • Solids Handling Improvements (Secondary Solids Thickening)	$14.0 million
Contract 1B-02	2009-2012	• Influent Pumping Station Rehabilitation (Screw Pumps, Screens and Odor Control) • Aeration System Enhancements • Aeration Blower Replacement • Administration Building Modifications • Site Improvements (access, parking, pervious pavements, green roofs, and retention areas) • Renewable Energy Technologies (solar walls and solar arrays)	$17.0 million
Contract 1B-03	2011-2013	• Hauled Waste Storage System • Electrical System Upgrades • Disinfection System Metering Pump upgrades	$2.5 million
		TOTAL	**$42.8 million**

3.4.3 CSO Diversion Station Improvements

Under the Phase I program, five CSO stations were upgraded to install new flow control gates and gate controls to implement the interceptor optimization program. During these upgrades, facility equipment was also upgraded, where necessary, to provide dependable operation. Other improvements were completed to address safety and odor issues. Table 3-4 summarizes the modifications made to each station.

These improvements were completed in several stages in bid construction contracts, via engineering consulting contracts, and self-performed by the utility itself. Some of the changes were driven by LRWWU's continued use of increasingly sophisticated gate controls and the development of the High Flow Management Program (discussed in Section 3.5), which required additional controls and monitoring. Overall, the Diversion Station Improvements program has cost about $7 million.

Table 3-4
Summary of CSO Diversion Station Improvements

CSO Station	Improvements
Beaver	• Two new influent flow gates, actuators, and other gate rehabilitation and controls
Merrimack	• New influent control gate, actuators, and controls • Three new gravity outfall gates, actuators, and controls • Odor control system and channel covers in wet area
Read	• New larger diameter (30-inch) interceptor connection pipe • New diversion weir and tideflex outfall gate
Tilden	• New influent and gravity diversion gates, actuators and controls • Odor control system and channel covers in wet area • Lighting and safety improvements in wet area
Warren	• New influent and gravity diversion gates, actuators, and controls • New channel screen upstream of siphons • Odor control system and channel covers in wet area • Lighting and safety improvements in wet area

3.5 High Flow Management Plan and Wet Weather Operations

Historically, LRWWU used to operate their CSO stations manually, requiring operators to drive to each station to open and close the CSO outfall gates. The Phase I LTCP identified the potential CSO capture that could be achieved if LRWWU was operate its interceptor system more systematically using instrumentation to store flow in the interceptor pipes before CSOs are discharged. Accordingly, over the last ten years, LRWWU has spent considerable effort to develop a high flow management plan that relies on real-time automated control of the flow control and CSO diversion gates at most of the CSO stations. This effort required several initiatives to identify the right equipment at each station to operate the control gates, to measure depths and flows, and to adjust automatic gate operations.

The result of the program is that LRWWU has achieved a very high degree of real-time control of flow in its combined sewer interceptor system and is fully utilizing the capacity of the interceptor pipe system for storage of wet weather flows using existing infrastructure. LRWWU has identified one final interceptor (the Read Interceptor) where, with the addition of a future new control structure, it could fully utilize storage capacity in the interceptor pipes.

3.5.1 Instrumentation and SCADA Development

Gates used to be powered by pneumatic-oil systems that became problematic and messy. For a period of time, LRWWU adopted the use of electric actuators for the gates. Although this approach eliminated the use of the messy oil system, the electric gates could not be modulated easy or responsively to rapidly changing flow conditions to achieve the higher degree of control that LRWWU sought in its wet weather operations. Later, LRWWU adopted the use of REXA actuators, an electro-hydraulic actuator at some stations that combined the use of an oil system in a self-contained actuator that didn't require the pump and accumulator of the typical pneumatic oil system. However, where feasible, LRWWU has updated and maintain the oil systems at some stations.

The deployment of instrumentation and measurement/control devices has also gone through a similar evolution as LRWWU has learned more about available technologies, new technologies have become available, and software has changed. LRWWU has optimized its SCADA system over the years using in-house staff and engineering consultants. Each CSO station (with the exception of First Street) has its own local programmable logic controller (PLC) to collect and monitor flow depths through the station, collect flow information at the diversions, and to control flow gates and pumps (with the exception of Walker and Read CSO Stations). Local control at most stations is also guided by what is happening within the existing system during any storm event. Either SCADA control software at the Duck Island WWTF or the WWTF Operators can make changes to flow control gates at each of the CSO stations to optimize flow capture across the system.

3.5.2 Flow Measurements

As discussed in section 2, there are a variety of methods that LRWWU uses at each CSO station to measure and estimate flow data including computations from flow over a weir (or over a downward opening gate), through an orifice (gate opening), past a mag meter, or through a parshall flume. In each of these situations, LRWWU has tried to confirm its computations by performing temporary metering adjacent to, or upstream and downstream of, the metering point in question. Adjustments to flow computations were made based on the temporary metering as necessary.

Flow depth measurements are critical at every station since control of the interceptor control gates, flow control gates, and diversion gates in every station are managed by these flow depth devices. LRWWU has evaluated the applicability of the location of each of these devices using temporary meters and based on a review of wet weather data to make sure that operations are optimized and accurate.

In addition, LRWWU completed a program that improved the flow measurements along the secondary bypass at the Duck Island WWTF. LRWWU examined the past measurements and device location, and determined that a more optimal device location was appropriate to improve the accuracy of the flow computations. This change has been implemented.

3.5.3 Interceptor Level Monitoring Program

As part of its high flow management program development, LRWWU deployed a set of interceptor level monitors at ten locations for a year to collect data during wet weather conditions. This program was performed to confirm the actual hydraulic conditions that occurred in the interceptor upstream of each CSO control station while being operated to maximize in-line storage. This program gave the operators a better confidence level that automated operations could work without impacting the sewer system and causing excessive surcharge. Depth profiles of the pipe were created for many storm events to figuratively show the actual hydraulic profiles of the pipe and its surrounding sewer connections. This program also assisted the operators and engineering staff to refine automatic operations so that additional storage potential was realized by further system surcharge (knowing that it would not impact adjacent services).

Along with the flow monitoring program, LRWWU completed a full topographic survey of the interceptor piping system to confirm as-built drawings of the pipe inverts and rims.

3.5.4 Development of High Flow Management Plan

From 2009 to 2011, LRWWU undertook a very exhaustive approach to developing, optimizing, and documenting its high flow management program for the combined sewer system. The high flow management plan integrated the system-wide control and flow monitoring devices with Duck Island WWTF operations to ensure that the maximum amount of flow was conveyed to Duck Island and flow was captured in the interceptor piping system before any CSOs were discharged. The plan is flexible to account for changing weather conditions (variably rainfall and spatially distributed rainfall), high river conditions (which impact the capability to gravity discharge at some CSO stations), and operating conditions at the WWTF.

For more than a year, data from each storm and the interceptor system response was individually collected and catalogue for discrete analyses. Local hydraulic profiles were created at each station to show the various HGLS running through the system for the set of storm conditions. Engineering staff and engineering consultants met periodically to review each batch of storm conditions and system response data to determine if there were any feasible adjustment to the control setpoints to improve the operation of each station control gate(s) and CSO diversion gates to capture more flow. Upstream conditions along the pipe and sensitive receptors (that might be impacted by sewer surcharging) were confirmed using topographic maps and the interceptor level monitoring data (see section 3.5.3).

Periodically, this data, analysis, and set point adjustments were discussed with the WWTF operators in a workshop to gain their understanding of system response and to help obtain their involvement in optimizing system operations during their shifts.

Ultimately, a High Flow Management Protocol (decision flow chart) and a detailed set of Wet Weather Operations Procedures were developed based on this effort. The High Flow Management Plan was submitted to the agencies on March 1, 2011. LRWWU considers this a "living document" and continues to periodically assess its performance based on a review of the flow and control data for individual storm events and trends data to ensure that measurement and control devices are properly maintained.

3.6 MS4 Compliance

As an operator of a municipal separate sanitary storm sewer (MS4), the city of Lowell completed its Notice of Intent for its Phase II NPDES General Stormwater Permit in 2001. The program included the city's proposed program to meet the six minimum control measures to address stormwater management including mapping, outfall inventories, public education, and system housekeeping. LRWWU has assumed general responsibility for the maintenance of this program and has submitted annual reports on the city's compliance progress. The city maintains its performance of the six minimum control measures to satisfactorily meet the objectives of the general stormwater permit.

In 2004, LRWWU completed a comprehensive inventory of the stormwater outfalls by field inspections of all the receiving water body banks. Photos and logs of each inspection were collected and compiled into a single binder. Sampling of dry-weather flow in outfalls was conducted and this indicated several outfalls with potential illicit connections. The city investigated these outfall piping systems and removed any illicit connections. Since this first inventory, the city has periodically, performed field inspections of the outfalls and collected samples of any dry weather flow. LRWWU estimates that each outfall is inspected on a rotating five year basis. Any dry weather samples that indicate the potential presence of an illicit connection are investigated immediately and illicit connections that are removed are documented in the annual reports.

The annual cost of the existing MS4 stormwater compliance program has been about $300,000.

3.7 CMOM Compliance

In accordance with its Administrative Order dated September 2010, LRWWU has completed the requisite assessments of its CMOM program, identified deficiencies, and is working to address those deficiencies and complete enhancements to its program. CMOM activities are documented in annual reports to the agencies including assessments of budgets, staff, and SSO reporting.

LRWWU immediately responds to and reports on each sanitary sewer overflow. The overflow conditions are documented and a capacity assessment is made to determine the cause of the overflow if it appears related to the public sewer system. LRWWU is reviewing its emergency response plan to fully document its SSO response procedures.

LRWWU has also developed a very comprehensive GIS system to document its sewer piping system. The GIS is continually maintained and updated by notations made by field staff based on their inspections and during the course of regulator field operations.

LRWWU performs a very aggressive program of inspection and rehabilitation of its collection system. As documented above, a significant amount of the collection system has been inspected, and rehabilitated as part of the sewer separation program. LRWWU's purchase of a closed circuit television camera truck has allowed the utility to perform its own inspections of sewers on a regular basis, continuing the assessment work that was started with the sewer separation program. LRWWU's goal is to perform 5 miles of cleaning and TV inspection each year. It is estimated that about 600,000 linear feet (113 miles) of sewer pipe has been inspected since 2005. This represents more than 50 percent of the collection system. The TV tapes are catalogued in an electronic repository and are available for comparison to future taping at any time to identify any pipe deficiencies that might occur over time.

It is important to note that TV inspection typically requires the full cleaning of the pipe; thus, approximately 40 percent of the sewer system has also been cleaned within the last ten years. Heavy cleaning is performed by a dedicated subcontractor.

LRWWU has also engaged separate contractors to assist them in either lining or replacing deficient sewer pipe as it is identified by TV inspections. It is estimated that LRWWU has completed about 16,000 linear feet of pipe replacement, which consist segment point repairs/ replacements from sewer manhole to manhole. In addition, LRWWU has completed the lining of more than 13,000 linear feet of deficient sewer identified based on the TV tapes.

LRWWU has spent more than $10 million over the last eight years on sewer system inspections, pipe replacement, and pipe rehabilitation (pipe relining).

3.8 Phase I Results

Table 3-5 shows the results of these programs with regard to CSO reductions over the years. In addition, LRWWU has shown positive results in its baseline flows at the Duck Island WWTF as the running annual average flow rate is about 26 MGD, which is significantly lower than the reported average of 30 MGD reported ten years ago.

Yearly CSO discharges are a function of the rainfall per year but the trend of CSO reduction is exceptionally good from nearly 1 billion gallons per year to 200 million gallons per year, an 80-percent reduction.

Table 3-5
Summary of Annual CSO Discharges (million gallons)

Year	CSO Station								
	Barasford	Beaver Brook	Merrimack	Read	Tilden	Walker	Warren	West	TOTAL
2005	83	40	96	0.17	48	30	466	190	952
2006	44	132	151	0.2	85	67	303	143	927
2007	22	52	81	1	59	11	216	15	456
2008	27	23	69	3	62	30	343	282	839
2009	7	18	53	0.02	38	11	143	55	325
2010	18	105	232	0	31	9	211	993	1598
2011	22	11	109	0	28	3	42	74	290
2012	8	3	42	0	12	3	20	36	125
2013	14	8	56	0	21	7	48	45	200

Note: *In 2010, LRWWU was completing improvements to its screw pumps at the influent pumping station at Duck Island and influent capacity was restricted during wet weather events.*

Section 4

Collection System Model and Baseline Conditions

4.1 Introduction

The Lowell SWMM collection system model (model) was redeveloped and updated from the previous model calibrated for the February 2002 Revised Draft CSO LTCP, as part of this LTCP update, to develop baseline conditions for the existing system. A flow metering program was conducted in the city from April through September 2012 to provide rainfall and flow data to update the model's calibration. The model is used as the basis for projecting design flow conditions and to develop and evaluate alternatives to meet the goals of the LTCP. A model is a valuable tool in evaluating alternatives under design storm conditions but its predictive capability is dependent on the quality and the variety of storm conditions captured during the monitoring program. Accordingly, it is always a good practice to continuously update SWMM models with additional flow and level monitoring data to better reflect field conditions for a range of wet weather event.

4.2 Flow Metering Program

The flow metering program included installation of temporary meters at 24 sites throughout the city from April 19 to September 23, 2012. A temporary rain gauge was located near the Walker CSO Station. Groundwater gauges were installed at three of the 24 metering sites. Metering locations are described in the model calibration memorandum included in Appendix B. A schematic and map of the metering network and CSO regulators is shown in Figure 4-1 and Figure 4-2, respectively.

Twenty-one storms with precipitation greater than 0.2 inches occurred during the flow monitoring period, as summarized in Table 4-1. Nine of these storms occurred during the spring and ranged from less than 2-week to 1-year average recurrence interval (ARI). The twelve storms that occurred during the summer were generally smaller, ranging from less than 2-week to 3-month ARI. Further analysis of rainfall data collected during the metering period and used for model calibration is presented in Appendix B.

4.3 Model Background

Computer models facilitate analysis of the complex hydraulic response of a combined sewer system (CSS) during wet weather. Models also help engineers assess the benefits of proposed system modifications to reduce CSO. As in prior modeling for Lowell's collection system, the EPA Storm Water Management Model (SWMM) was used to dynamically simulate sanitary wastewater flow, stormwater runoff, and the conveyance hydraulics of the wastewater collection system.

Figure 4-1
Schematic of Meter Locations

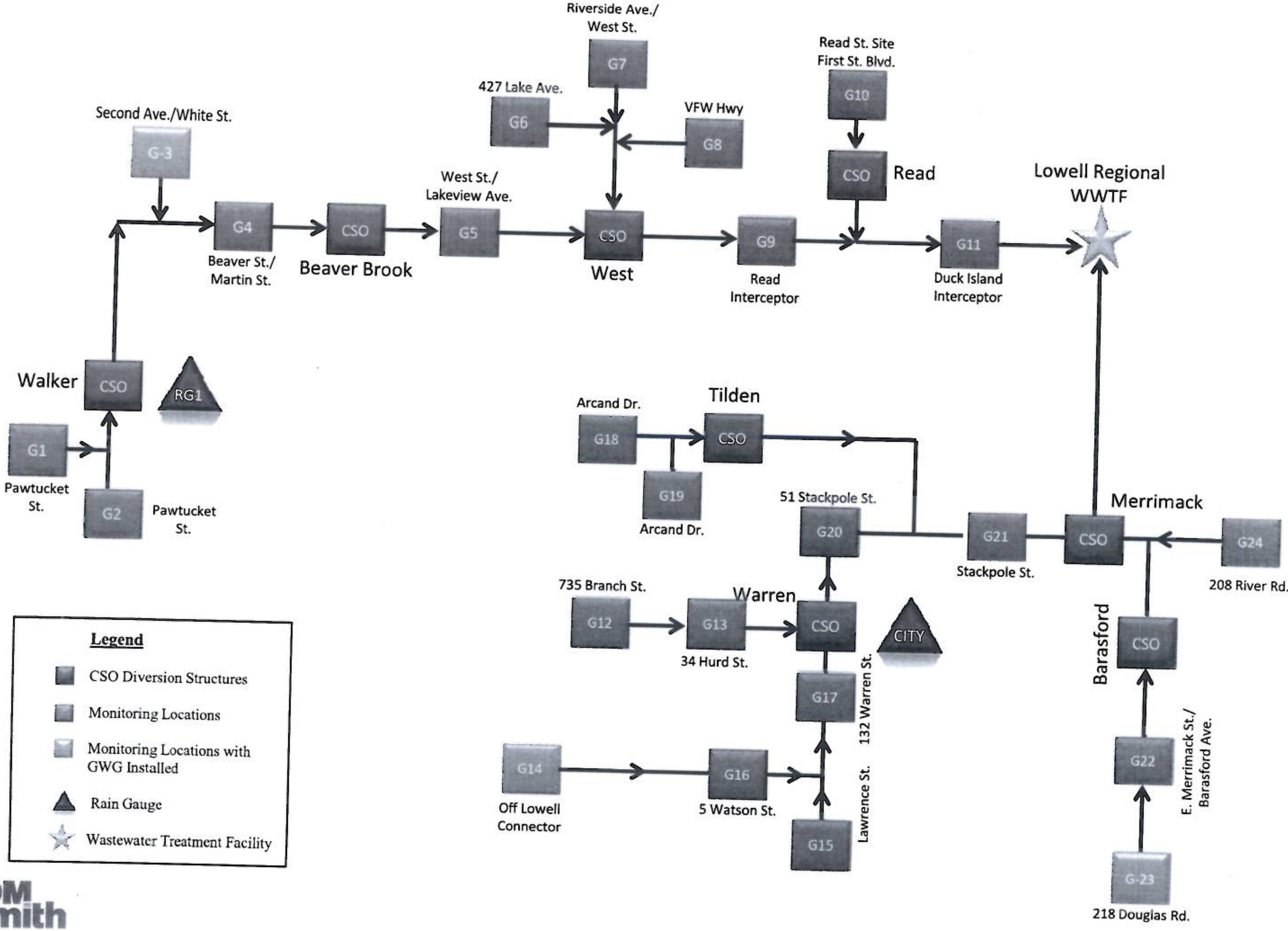


Table 4-1 Wet Weather Events

Date	Depth (in)	Duration (hr)	Peak Hour Intensity (in/hr)	Recurrence Interval[1]
04/22/2012 08:45	2.62	33	0.34	1-year
09/04/2012 06:00	1.65	26	0.97	3-month
05/09/2012 18:45	1.24	20	0.20	2-month
06/02/2012 06:30	1.12	19	0.29	1-month
08/11/2012 08:15	0.92	10	0.76	1-month
05/01/2012 04:45	0.74	10	0.16	1-month
06/13/2012 00:30	0.74	13	0.11	1-month
06/25/2012 10:15	0.62	4	0.30	1-month
08/15/2012 23:30	0.57	9	0.24	1-month
05/22/2012 04:00	0.53	17	0.13	2-week
07/18/2012 13:30	0.50	1	0.50	3-month
05/15/2012 13:45	0.40	10	0.19	2-week
09/18/2012 18:15	0.38	9	0.30	2-week
05/08/2012 05:30	0.35	18	0.07	2-week
06/23/2012 16:15	0.35	2	0.33	2-week
07/04/2012 04:45	0.33	4	0.16	2-week
08/17/2012 21:45	0.32	3	0.27	2-week
06/04/2012 01:45	0.31	25	0.06	< 2-week
08/28/2012 06:15	0.31	4	0.24	2-week
08/15/2012 07:45	0.29	2	0.24	2-week
07/28/2012 16:45	0.26	6	0.07	2-week

[1]Based on total depth and total duration of event

SWMM was first developed in 1971 and has undergone several major upgrades. It is widely used for planning, analysis, and design of stormwater combined, and sanitary sewers. The model utilizes rainfall-runoff characteristics for subcatchment areas within a sewershed or watershed, and routes water through a piping system. It can simulate a wide variety of conduit types, diversion structures, weirs, and pumps. The model dynamically simulates hydraulic grade lines (HGLs), using dynamic wave routing, allowing it to compute free-flowing or surcharged conditions over an extended period of time.

SWMM 4 was used to develop Lowell's original CSS model, as described in Appendix B of the *2002 Revised Draft Long-Term CSO Control Plan/Draft Environmental Impact Report* (EOEA #12059). SWMM has been significantly updated since 2002; thus, the SWMM 5 (version 5.22) was used to develop the updated model of the city's system presented here.

4.4 Model Updates

The original CSS model was updated to reflect existing conditions (based on the significant number of system improvements completed by LRWWU during the Phase I LTCP program, as discussed in Section 3) and to refine the model configuration in high priority areas of the system. Pipes with a 42-inch or larger diameter were included, along with smaller pipes included in the 2012 metering program, or otherwise judged important components of the system. The model pipe network was extended to include the following:

- Interceptor along Marginal Street and Pawtucket Canal, extending from Walker Interceptor to Warren CSO station;
- Additional pipes upstream of Warren CSO station to Stevens Street and Billerica Street;
- Additional pipes upstream of West CSO station to refine the representation of flows from Dracut, including stormwater flows from Humphrey's Brook, Hovey Field, and the Billings Street wetland;
- Additional pipes upstream of Tilden CSO station to Broadway Street and Market Street; and
- Additional pipes upstream of Barasford CSO station to the Wentworth Avenue and Douglas Road area.

Other model updates include:

- Refined subcatchment area delineations considering topography, sewer connectivity, and existing combined areas;
- Updated system imperviousness using MassGIS (published in 2009 from data collected in 2005);
- Updated soil properties assigned to subcatchment areas based on typical values used in other urban collection system models in New England;
- Updated invert and manhole rim elevations based on 2012 interceptor drawings (CDM Smith), LiDAR data, and Lowell sewer system maps;
- More detailed representation of CSO stations (gates, weirs, channels, and pumps) based on schematics from the city's High Flow Management Plan (HFMP) and available drawings for each station;
- Rules for gate operations at the CSO stations based on the city's HFMP and station operating manuals, as programmed in the city's SCADA system;
- Integration of SWMM's groundwater component to refine seasonal variation of infiltration for long-term simulations; and
- Representation of the Merrimack River, Concord River, and Beaver Brook to refine stage boundary conditions at CSO outfalls and allow for more accurate representation of the effect of tailwater conditions on collection system hydraulics. River cross-sections were obtained from the Merrimack River hydraulic model used for the 2004 Corps of Engineers Merrimack River

Watershed Assessment Study and recent Upper Merrimack River Study. Flow records for the Merrimack River at Lowell (USGS 01100000) were used and scaled based on watershed area to represent flow in the Concord River and Beaver Brook.

The updated model includes the nine CSO stations, 350 conduits, and 200 subcatchments. The subcatchments include 3,700 acres of combined sewer area and 4,200 acres of separated sewer area, totaling 7,900 acres within the city. The model pipe network and subcatchments are shown in Figures 4-3 and 4-4, respectively.

4.5 Model Calibration and Validation

The updated sewer model was calibrated to dry weather and wet weather based on data collected during the 2012 flow metering program. LRWWU provided WWTF flow data at 15-minute intervals for the calibration period and at daily intervals for 2010 through 2012. LRWWU also provided 15-minute data from their SCADA system for flow, depth, and gate operations at the CSO stations. The model was then validated to the depth and flow data from the SCADA system for the 2012 year.

LRWWU maintains a rainfall gauge at the Warren CSO station that records at 15-minute intervals. Cumulative rainfall at Warren station was compared with National Weather Service COOP observers at Hanscom Field, Lawrence, MA, and Hudson, NH for the calibration period. As the Warren gauge closely tracked the other gauges, it was used for calibration. The model was adjusted to minimize differences between observed and simulated timing of peaks, peak flow, velocity, volume, and depth at each metered location. Model calibration and validation are discussed in a technical memorandum included as Appendix B.

4.5.1 Dry Weather Calibration

Dry weather flow includes diurnally varied sanitary flow along with infiltration from groundwater. Groundwater levels and pipe infiltration were directly simulated using SWMM's groundwater simulation component. Initial groundwater and aquifer parameters were based on typical values used in other urban collection system models in New England and then were adjusted to match long-term seasonal groundwater trends observed in the WWTF flow data. Average sanitary flow during dry weather was estimated at each temporary meter location from conditions observed over a seven-day dry period from August 19–25, 2012. Estimated flow contributions from Tyngsboro, Tewksbury, Dracut, and Chelmsford were subtracted from temporary meter flows to allocate flows within Lowell and for each outside community. Hourly and daily patterns were developed from the metering and WWTF flow data and applied to the average sanitary flows.

The model was initially calibrated to a dry weather period from August 19–25, 2012. Initial dry weather flow estimates were adjusted to match measured discharge data at the meter locations. Manning's coefficients for conduits was initially set to 0.013 and adjusted between 0.011 and 0.025 to calibrate depth and velocity. Higher calibrated Manning's coefficients may be due to combined effects of pipe age, unknown obstructions, and sediment accumulation. This dry-weather calibration was discussed with LRWWU staff to help identify system conditions that could be creating additional headlosses and to gain input from LRWWU on other operational conditions that could be used to update the calibration. Based on this SWMM model adjustments were made. Sediment was added to some conduits to improve depth calibration, based on comments from LRWWU and where sediment accumulation seemed likely based on metering data and pipe configuration. Form loss coefficients were applied at some conduits to account for head loss due to pipe bends or other obstructions. One example is a root ball just downstream of the Tilden CSO Station, which was discovered by staff working on the system after the 2012 flow monitoring program was completed. Adjustments of the manning's coefficient along this pipe to reflect the temporary root ball helped in the calibration of this pipe segment.

Following calibration to the August dry weather period, model results were also compared to data from a dry weather period from May 17–21, 2012. Dry weather calibration plots for the temporary meters and depth sensors at the CSO stations are included in Appendix B. Overall, a good dry weather calibration was achieved.

4.5.2 Wet Weather Calibration

The model accounts for various wet weather flow contributions to the sewer system, including drainage from combined areas, infiltration and inflow (I/I) from separated areas in Lowell and from sewered areas in Chelmsford, Dracut, Tewksbury, and Tyngsboro, and drainage from Dracut including Humphrey's Brook, Hovey Field, and the Billings Street wetland.

Although 2012 was a reasonably dry year, three principal storms occurring on April 22, May 9, and June 2, 2012 were selected for primary wet weather calibration. Statistics for these events are provided in Table 4-1.

LRWWU provided 2012 SCADA data for all its CSO stations, except First Street, which is not operated. The SCADA output included time series of gate operations (percent open), channel and interceptor depths, and station flows. For the calibration period, the SCADA data time series for the gate operations were used directly in the model to ensure that the correct gate settings were being applied. Control logic for the gates was later used for design storm and long-term simulations. The control logic is based on the 2013 High Flow Management Plan and operation and maintenance (O&M) manuals for the CSO stations.

Subcatchments contributing impervious area and width were adjusted to calibrate runoff into the system. Manning's and loss coefficients were further modified as necessary to improve depth and velocity calibration. Discharge coefficients for gates at the CSO station gates were also adjusted to match channel depths indicated by SCADA. A root ball was discovered downstream of the Tilden CSO station and was represented with loss coefficients and 1.5 feet of sediment in a 36-inch pipe. The root ball was assumed to be in place for the duration of the calibration period, as suggested by LRWWU. The root ball was removed from the system and this was also removed from the model for the later analyses.

Wet weather calibration plots for each principal storm for the temporary meters and CSO stations are included in Appendix B, along with scatter plots that were generated to assess the overall wet weather calibration for the entire metering period. Calibration was assessed according to the Wastewater Planning Users Group (WaPUG) criteria (industry standard) for peak flow, volume, and depth.

4.5.3 Model Validation

Groundwater Infiltration

Following wet weather calibration, the model was run from 1987 through 2012 to ensure that seasonal variation of infiltration was adequately simulated. Daily precipitation data from the Hudson, NH gauge (274234) was synthetically disaggregated to hourly intervals for use in the long-term simulation.

Simulated groundwater levels were compared to observed water table elevations at the USGS well in Wilmington, MA (MA-XMW 78, ten miles southeast of Lowell). Hydrographs comparing simulated and observed groundwater levels are included in Appendix B. The model reasonably mimics seasonal groundwater trends observed over the 26-year simulation period.

A continuous simulation from 2010 through 2012 was also performed to assess the simulated infiltration into the collection system. The simulated and observed flows at the WWTF were compared and show similar trends in the seasonal variation of the groundwater infiltration.

2012 Validation Simulation

The model was run for 2012 to compare simulated annual overflow with reported values. Control logic was applied in the model for gate operations at the CSO stations based on the April 2013 HFMP protocol and O&M manuals for each station. Representation of the root ball downstream of the Tilden CSO station was included in the model for the full simulation, although the actual duration that the root ball was in place is unknown.

Reported and simulated annual CSO statistics for 2012 are provided in Appendix B. Overall, the model results match reasonably well with the reported values. As discussed in the model calibration memorandum (Appendix B), the discrepancies are likely due to manual gate operations and simulating exact set points used in the control logic for gate operations. With additional flow and level monitoring, the model can be continuously refined to increase its effectiveness as a tool in determining the system benefits of completed projects during design storm conditions as LRWWU makes progress towards reducing their CSO discharges.

Annual Average WWTF Flow

Based on continuous simulation of a five-year representative period using precipitation data from 2005 to 2009, annual flow at the WWTF averages 29 to 33 mgd, with an overall average of 30 mgd (Appendix B). These results are similar to the existing reported average flow rate at the WWTF, which is approximately 28 mgd.

July 2013 Storm

The largest storm during the 2012 calibration period was a 1-year event on April 22. The model was also run for a recent storm event that occurred on July 1, 2013, using data provided by LRWWU from the rain gauge at the Duck Island WWTF. This storm had a total depth of 1.6 inches and peak 15-minute depth of 0.6 inches with a 2-year 3-hour ARI. Simulated and observed depths at the CSO stations and flow at the WWTF were similar in most places (Appendix B).

Based on the overall calibration and validation simulations performed, the model is considered calibrated for the field data that was collected and can be used for conceptual assessment of the existing system and analysis of the impacts of planned and potential improvements. The use of additional flow and level monitoring to refine the model will be very beneficial to simulate wet weather impacts in planned project areas during design storm conditions.

4.6 Model Projections

Once the model was calibrated and validated, it was applied to project flows for design storm events. Both design storms and long term simulations were developed to analyze the existing collection system under a variety of wet weather conditions.

4.6.1 Design Storms

The 3-month, 6-month, 1-year, 2-year, and 5-year design storms used for the 2002 LTCP were also used for this study. These storms are described in Appendix C. These events are selected from the long term record at Boston Logan Airport; they are not synthetic design storms. Synthetic design storms can be too intense at the peak of the storm causing high peak flow projections. Because the design events used here are measured storms, their corresponding CSO volumes are more closely aligned with CSO at the corresponding recurrence interval, and correlate well with results from the long term simulations.

Average groundwater conditions were applied for design storm simulations. Boundary conditions at the CSO outfalls were based on simulated river stages for each storm date. Although the wet-weather treatment design capacity at the WWTF is 110 mgd, the operating rules in the model were set to maintain a maximum of 90-100 mgd at the WWTF for baseline conditions simulations, based on existing operations at the WWTF (See section 2). CSO volumes and duration for the design storm simulations based on the updated model are summarized in Table 4-2. System-wide CSO ranges from 14 MG for the 3-month event to 180 MG for the five-year event.

4.6.2 Long-term Simulations

Average Annual CSO Projections

Continuous simulation of a five-year representative period from 2005 to 2009 was completed to estimate average annual CSO. Selection of the five-year period is discussed in Appendix C. Results of these simulations are summarized in Table 4-3. Average annual CSO volume for existing conditions based on the updated model is 171 MG. The differences in estimated CSO discharge between the original and updated models are likely due to the model updates described above, and the updated calibration with 2012 flow data.

Estimated Percent Capture

The five-year baseline simulation was also analyzed to compute percent capture for the existing sewer system. Percent capture was characterized by the following equation:

Percent Capture = 1 - (CSO Discharged Flow/ Total Wet Weather Flow)

Total wet weather flow was computed as the sum of CSO discharges and total flow at the WWTF during wet weather, including dry weather flow and groundwater base flow. The total flow contribution from Chelmsford, Dracut, Tewksbury, and Tyngsboro was subtracted from the total WWTF flow. The duration of wet weather was estimated by comparing dry weather flow with total flows entering the sewer system. Analysis showed that flows entering the system were 10 percent or higher than dry weather levels 7.5 percent of the time. This yields an average annual wet-weather duration of 27 days.

Based on calculations using the five-year continuous simulation for existing conditions, wet weather percent capture for the system is 87 percent. In the 2002 LTCP report, capture was estimated to be 88 percent prior to Phase I improvements. However, the methodology used in that report accounted for flows from sanitary sewered outside communities as part of the capture calculation. The method used for this report excludes flow from outside communities as part of the capture fraction and thus yields a lower capture rate. If those flows are included in the capture calculation, annual wet weather capture is 89 percent.

Table 4-2 Design Storm CSO Summary – Baseline Conditions

NPDES ID	CSO Description	3-Month Volume (MG)	3-Month Duration (Hours)	6-Month Volume (MG)	6-Month Duration (Hours)	1-Year Volume (MG)	1-Year Duration (Hours)	2-Year Volume (MG)	2-Year Duration (Hours)	5-Year Volume (MG)	5-Year Duration (Hours)
North Bank											
007	Beaver Brook	0.3	1.75	0.7	1.50	1.5	2.25	4.0	2.75	17.6	7.00
012	First Street	-	-	-	-	-	-	-	-	0.2	0.75
011	Read Street	-	-	-	-	-	-	1.2	0.75	5.0	2.00
002	Walker Street	-	-	-	-	0.5	0.50	1.7	1.50	6.3	5.00
008	West Street	2.4	3.50	4.0	4.75	7.4	5.25	10.6	5.50	29.1	11.50
South Bank											
030(1)	Barasford Ave.	-	-	-	-	-	-	1.6	0.50	11.7	2.00
030(2)	Merrimack	6.2	4.75	10.4	6.75	9.2	4.75	13.9	6.00	40.6	13.00
027	Tilden Street	0.9	1.00	1.1	1.00	3.2	2.50	6.2	3.00	16.3	5.50
020	Warren Street	3.7	2.25	6.4	3.25	9.6	3.00	19.3	5.00	52.4	10.75
	Total	**13.6**		**22.7**		**31.5**		**58.6**		**179.3**	

Table 4-3 Average Annual CSO Statistics – Baseline Conditions

NPDES ID	CSO Description	Volume (MG/yr)	Duration (hrs/yr)	Events (discharges/yr)
North Bank				
007	Beaver Brook	7.5	14	9
012	First Street	–	–	–
011	Read Street	1.6	1	3
002	Walker Street	0.8	1	2
008	West Street	24.6	31	10
South Bank				
030(1)	Barasford Ave.	1.8	1	1
030(2)	Merrimack River	64.8	52	18
027	Tilden Street	14.9	14	13
020	Warren Street	55.2	30	20
	Total	**171.1**		

Section 5

Water Quality Objectives

5.1 Introduction

All discharges to the waters within the Commonwealth of Massachusetts should meet the requirements of the federal Clean Water Act (CWA, passed in 1972) and the state's Surface Water Quality Standards (WQS) as described under 314 CMR 4.00. The water quality standards identify the anticipated recreational, fisheries, water supply and other designated uses of the receiving waters and provide numerical (and narrative) standards for key pollutants that should be achieved to maintain these designated uses.

When it rains, pollutant loads from surface water runoff are discharged to receiving waters from both point and non-point sources. Non-point sources are difficult to identify, quantify, and control, but some means of non-point regulation should be established as point sources shouldn't receive the main focus. However, point source loads - such as stormwater drain outfalls and CSO outfalls – can be located and are more easily characterized. Thus, point source loads receive more regulatory attention. The USEPA administers these point source discharges via the NPDES permit program. The Duck Island WWTF and CSO outfalls each have a unique NPDES permit number while the city's stormwater outfalls are covered under a blanket general permit as part of the Phase II Stormwater NPDES program.

The principal receiving water for Lowell's CSO discharges is the Merrimack River. The Warren CSO Station discharges to the Concord River, just upstream of the urbanized downtown portion of the river that is part of the former locks and canals and has very limited access for water recreation. The Beaver Brook CSO Station discharges to Beaver Brook at a point about 300 feet upstream of the mouth of the brook at the Merrimack River; thus, this discharge is essentially into the Merrimack River. There are no known recreational uses of the brook in this segment.

Discharges are held to numeric limits in order to maintain the designated uses of the receiving water. If these uses are unattainable, given natural conditions and/or due to existing discharges that cannot be removed, the regulations allow a modification of the receiving water uses. However, the regulatory modification process requires a comprehensive review of alternatives for intermediate pollutant control levels and estimates of costs, and involves the public and interested parties.

Both federal and state agencies recognize that compliance with state quality standards for CSO discharges is costly. Accordingly, both governments have developed separate, but similar, CSO control policies to guide the abatement of CSO discharges given the technical, social, and economic challenges for each community.

This section presents a summary of the federal and state CSO policies, and the water quality standards for the Merrimack River, Concord River, and Beaver Brook in Lowell. The section also includes a summary of existing river water quality data and analyses that provide an understanding of the current status of the rivers with respect to the standards and potential attainment of any impacted designated uses. This information is used to evaluate the receiving water benefits that could result with the implementation of each of the various CSO control alternatives (developed and analyzed in the proceeding sections).

5.2 USEPA CSO Policy

Under the federal CSO policy, CSO discharges are subject to both the technology-based and water quality based requirements. The CSO Control Policy, issued in April 1994 provides the EPA guidance for controlling CSOs. A two-part approach to CSO control is incorporated into the policy: (1) the implementation of best management practices called the Nine Minimum Controls, and (2) the development and implementation of an LTCP provided the implementation of the NMCs are not adequate on their own to meet state water quality standards.

5.2.1 Nine Minimum Controls

The minimum technology-based controls are the nine minimum controls (NMCs). The CSO Control Policy required all communities to implement the NMCs by January 1997.

Lowell's compliance with the NMCs was detailed in a previous CDM report entitled "City of Lowell, Massachusetts Report on Nine Minimum Control Measures" dated April 1998. To date, the city has acted on or fully implemented each of the recommendations made in that 1998 report.

Nine Minimum Control Measures:

1. Monitoring to characterize CSO impacts and the efficacy of CSO controls.
2. Proper operation and regular maintenance programs for the sewer system and the CSOs
3. Maximum use of the collection system for storage
4. Review and modification of pretreatment requirements to minimize CSO impacts
5. Maximize flow to the POTW for treatment
6. Prohibition of dry-weather CSOs
7. Control of solid and floatable materials in CSOs
8. Pollution prevention programs
9. Public notification of CSO occurrences/impacts.

5.2.2 Long-term Control Plans

The NPDES entity (EPA Region 1 in the case of Lowell) determines whether the NMCs satisfy the technology-based requirements of the CWA. If further controls are necessary to meet water quality standards, then the NPDES authority will require the development of a Long-Term Control Plan (LTCP).

EPA issued the Draft Guidance on Implementing Water Quality Based Provisions of CSO Control Policy. This document indicates that if the receiving water is on the State's 303(d) list for the development of a total maximum daily load (TMDL), then the TMDL studies and LTCP should be linked, and should include a schedule for WQS reviews. To date, however, only a draft TMDL has been developed for the Merrimack, Concord River, and Beaver Brook, and no final TMDL is in place for either receiving water to define all point and non-point sources of pollution.

By the requirements in the Clean Water Act, CSO discharges that remain after implementation of the CSO controls must not interfere with the attainment of state's WQS. Under the CSO Control Policy, communities with combined sewer systems are expected to develop a LTCP to provide for attainment of the water quality and uses over a reasonable period of time.

The EPA CSO Control Policy presents two alternatives to selecting long term control plans for CSO's: the "presumptive approach" and the "demonstrative approach".

5.2.2.1 Presumptive Approach

The "presumptive approach" is based on the presumption that achievement of certain performance criteria will be sufficient to meet current applicable water quality standards. The presumptive approach involves meeting one of the following three criteria:

- No more than an average of 4 overflow events per year;
- Elimination or the capture of no less than 85% by volume of the combined sewage collected in the combined sewer system during precipitation events on a system-wide annual average basis; or
- Elimination or removal of no less than the mass of pollutants identified as causing water quality standards impairment.

As part of the presumptive approach, there must also be sufficient information available to indicate that these levels of control can reasonably be expected to meet the state water quality standards. Communities following the presumption approach are also expected to conduct post LTCP monitoring to show that water quality standards are being met. If a community is at no more than 4 overflows per year or captures 85% of their flow, and instream water quality standards are still being exceeded, then further CSO controls are needed.

5.2.2.2 Demonstrative Approach

The demonstrative approach (that favored by DEP and EPA Region I) was developed to address instances where compliance with the presumptive approach would result in greater investments in control than necessary to achieve water quality standards. Under the demonstrative approach, communities collect and present data in the LTCP that is sufficient to show that the proposed control alternative is adequate to meet appropriate water quality standards. The CSO Control Policy lays out four criteria for successful use of the "demonstrative approach." A LTCP should show that the:

- CSO control program will protect water quality standards unless the standard cannot be met as a result of natural conditions or other pollution sources;
- Overflows remaining after implementation of the control program will not prevent the attainment of water quality standards;
- Planned control program will achieve the maximum pollution reduction benefits reasonably attainable; and
- Planned control program is designed to allow cost effective expansion or cost effective retrofitting if additional controls are subsequently determined to be necessary to meet water quality standards.

When water quality standards cannot be met because of natural conditions or other pollution sources, a TMDL or other means should be used to apportion pollutant loads within the watershed.

5.3 Massachusetts Policy for Abatement of CSOs

In August of 1997, the Commonwealth issued its own CSO Control policy. This policy is similar to the EPA policy in many ways, but also has several significant differences.

States are required to develop water quality standards applicable to their water bodies. While EPA reviews and approves these standards, the establishment of the standard is the responsibility of the state. In Massachusetts, any NPDES permit for a CSO discharge must comply with Massachusetts Surface Water Quality Standards (314 CMR 4.00). Massachusetts has chosen to designate all waters in the state as fishable and swimmable. For freshwater, all water bodies were originally designated as either Class A (drinking water source) or Class B (swimmable). For marine waters, all water bodies are either Class SA (shellfish) or Class SB (shellfish restricted).

Massachusetts's regulatory options for CSO control are implemented through different water body classifications, as follows:

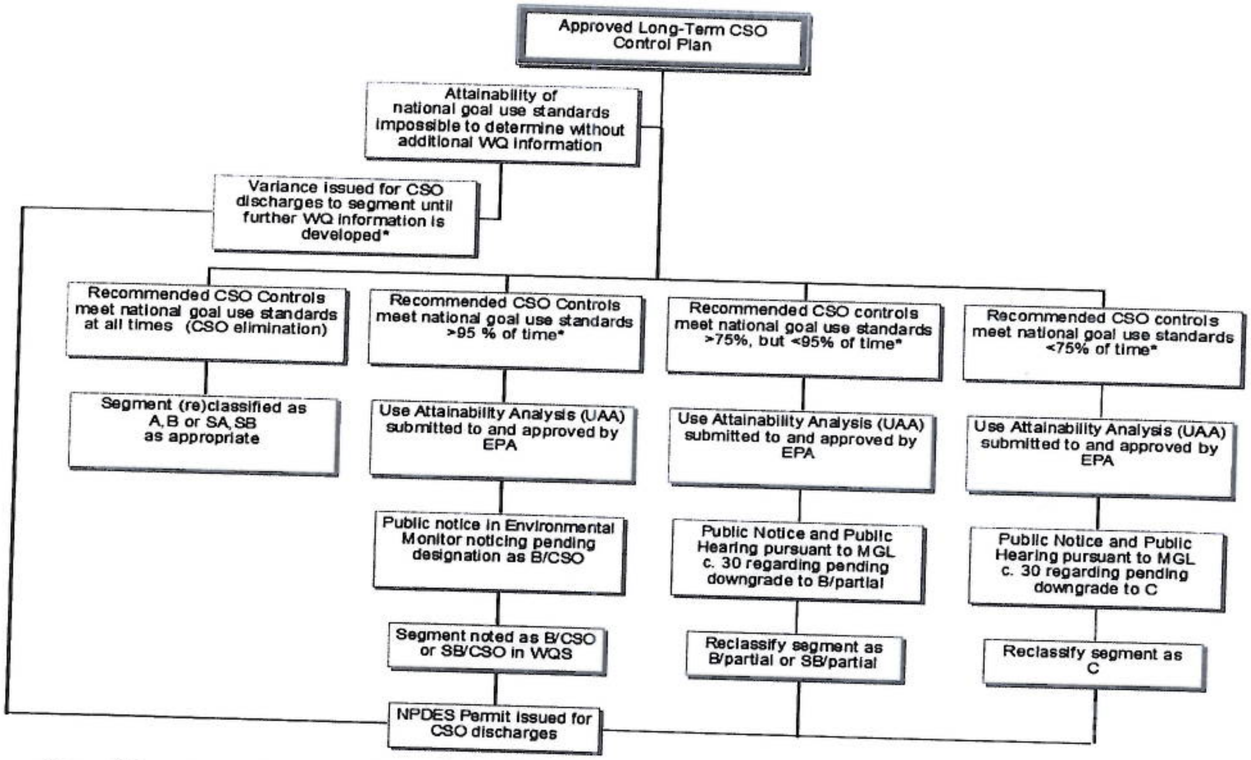
- Class B or SB – No discharges are allowed that impact WQS (such as untreated CSO dischargers).
- Class B (CSO) - CSOs may remain but must be compatible with water quality goals of the receiving water. The water body must meet uses more than 95 percent of the time. DEP considers 4 overflows events per outfall per year as satisfying the 95 percent time period. Two water bodies in the state have been re-classified as B(CSO).
- Variance - CSOs may remain under a short-term modification of water quality standards. Currently, portions of the Charles River have a variance while studies are underway to determine the final designation. Also, GLSD located downstream of Lowell will be requesting a variance as part of their Phase II CSO LTCP.
- Partial Use Designation - CSOs may remain with moderate impacts resulting in impairment of water quality goals. Moderate impacts are defined as short-term impairments and water quality standards would be met 75 percent of the time.
- Class C - Where the State is certain that the CSOs will prevent the attainment of national use goals more than 75 percent of the time, the water body is classified as Class C.

Under the Massachusetts program, one permanent solution to CSO control, besides river reclassification to BCSO of the water body, is the complete elimination of the CSO discharge. This has usually been interpreted to mean almost complete separation of the combined sewer system, even though there is strong evidence to suggest that the stormwater created as a result of the separation may itself cause exceedances of the water quality standards.

The permittees must go through a number of technical and procedural steps to permanently reclassify the receiving water, or to provide temporary modifications to the classification. The steps associated with this process are included in Figure 5-1. The procedural steps involve the notice of proposed changes in the Environmental Monitor, and the conduct of various public meetings and hearings and the official publication of the reclassification of the State's Water Quality Standards Regulations.

Underlying these procedural steps are supporting technical analyses that show that fully achieving the designated Class B uses everywhere all the time is not attainable. The studies are generally called Use Attainability Analyses (UAA). In order to permanently reclassify the receiving waters, the UAA must show that one of the following conditions exists:

1. Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or



*One of the criteria of 314 CMR 4.03(4) must be met

Figure 5-1
CSO Controls – WQS Coordination

2. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or

3. Naturally occurring pollutant concentrations prevent the attainment of the use; or natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met; or

4. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or

5. Controls more stringent than those required by sections 310(b) and 306 of the Act would result in substantial and widespread economic and social impact.

According to DEP policies, the justification for a variance, which are temporary rather than permanent suspensions of the designated uses, involve the same substantive requirements as a change in use although the evaluation needed are less rigorous. As discussed later in this report, reasons 1 and 2 stated above may be applicable to the Merrimack River, Concord River and Beaver Brook, respectively, and may warrant a variance from their intended uses.

5.4 River Classification and Uses

5.4.1 Classification

All water bodies, streams, rivers, ponds, lakes, and coastal areas in the state are classified in the Massachusetts Surface WQS 314 CMR 4.00 (December 2013). These standards designate uses of the waters such as water supply or shellfishing. To protect the designated uses, the MADEP prescribes the minimum water quality criteria required to sustain the designated uses.

The Merrimack River from the Rourke Bridge (Wood Street, above all of the CSOs) in Lowell to the ocean at Salisbury, the lower segment of Beaver Brook and the lower segment of the Concord River are the receiving waters for this study, see Figure 5-2 and 5-3. These river segments are designated as shown in Table 5-1. The Merrimack from Lowell to Haverhill and the lower segment of the Concord River are both Class B, with a designated use of warm water fisheries. The lower segment of Beaver Brook is Class B, with a designated use of cold water fisheries. The Class B designation also includes other uses, defined as:

> *Class B - These waters are designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. Where designated in 314 CMR 4.06, they shall be suitable as a source of public water supply with appropriate treatment ("Treated Water Supply"). Class B waters shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.*

The Merrimack River is Class B from the Haverhill city line to the Little River. From the Little River to the coast, the Merrimack River is Class SB. The SB designation is for marine waters, the lower segment of the Merrimack is influenced by ocean tides. Uses designated for Class SB waters in the state include:

> *Class SB - These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas). These waters shall have consistently good aesthetic value.*

The Merrimack River uses are qualified as warm water fisheries in the Class B portion of the river and for shellfishing in the SB portion of the River. However, the Merrimack River from Lowell to Amesbury has very low salinity and does not support existing or potential shellfishing use in the Lowell reach under Class SB.

5.4.2 Uses and Supporting WQS

There are four major categories of potential uses of the Class B and SB rivers in Lowell – aesthetics; habitat for fish, wildlife, and aquatic life; primary (swimming) and secondary (boating) contact recreation; and water supply.

Aesthetics

The aesthetics of the river are an important asset to Lowell. The city has urban renewal projects that focus on land adjacent to the river bank. The riverfront is also the setting for several city parks, and a

Table 5-1
Receiving Water Classification

River	River Segment	Mile Points	Class	Designated Uses
Beaver Brook	State line to confluence with Merrimack River	4.2-0.0	B	Cold Water
Concord River	Confluence of Assabet and Sudbury to Billerica Water Supply Intake	15.7-5.9	B	Warm Water; Treated Water Supply
Concord River	Billerica Water Supply Intake to Rogers Street	5.9-1.0	B	Warm Water
Concord River	Rogers Street to confluence with Merrimack River	1.0-0.0	B	Warm Water; CSO
Merrimack River	State line to Pawtucket Dam	49.8-40.6	B	Warm Water; Treated Water Supply; CSO
Merrimack River	Pawtucket Dam to Essex Dam, Lawrence	40.6-29.0	B	Warm Water; Treated Water Supply; CSO
Merrimack River	Essex Dam, Lawrence to Little River, Haverhill	29.0-21.9	B	Warm Water; CSO
Merrimack River	Little River, Haverhill to Atlantic Ocean	21.9-0.0	SB	Shellfishing; CSO
Merrimack River	The Basin in the Merrimack River Estuary, Newbury and Newbury Port	-	SA	Shellfishing

Source: 314 CMR 4.00 Massachusetts Surface Water Quality Standards

These state WQS indicate that the waters should be free from color and turbidity and floating, suspended, and settleable solids in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class. Oil, grease and petrochemicals that produce a visible film on the surface of the water or impact aquatic life are also prohibited.

Fishing

State and Local parks, such as the Lowell National Historical Park, provide public access for fishing. Additionally, numerous riverbank access points and boat launch points are available. Species of fish found in the Lower Merrimack River are listed in Tables 5-2. The Merrimack River is also an anadromous fish run. The fish include River Herring, American Shad, and Atlantic salmon as the three main species in historic data, but also the Sea Lamprey, American Eel, and Stripe Bass. For the most recent reported year, in 2012, 8,992 River Herring, 21,396 American Shad, and 137 Atlantic salmon passed the fish lift at the Essex Dam in Lawrence. (Fish and Wildlife Service, 2014)

WQS indicate that waters shall have a temperature not to exceed 68° F (20° C) for cold-water fisheries and 83o F (28.3o C) for warm-water fisheries. Dissolved oxygen levels must also be maintained at 6.0 milligrams per liter (mg/l) for cold-water fisheries and at 5.0 mg/l for warm-water fisheries. Solids and oils and grease should be minimized to avoid benthic loadings along the river bottom, deleterious effects to aquatic organisms, and tainting or undesirable taste in edible portions of fish.

The Massachusetts Department of Public Health has issued a Freshwater Fish Advisory for mercury for the Merrimack River from above the Essex Dam in Lawrence to the state line in Tyngsborough. However, there are no reported issues based on these standards affecting fish, the Massachusetts Health and Human Services has issued a Public Health Fish Consumption Advisory for White Sucker and Largemouth Bass from this waterbody. The Merrimack River meets the fishing use for the section in Lowell.

Because mercury is only present in very small concentrations, if at all, in Lowell's CSOs, these discharges do not impair fishing in the lower Merrimack River.

Shellfishing

The Merrimack River below the Route 95 Bridge in Newburyport and Salisbury is a designated shellfish area, but the area has been closed for more than 20 years because of high bacteria counts. In March 2006, the Massachusetts Division of Marine Fisheries announced the re-classification and re-opening of the Merrimack River shellfish flats in Newburyport and Salisbury to the conditional harvesting of soft-shell clams.

Water quality testing by Marine Fisheries confirmed the river meets moderately contaminated criteria during dry weather, for a Conditionally Restricted classification. Marine Fisheries sampling also demonstrated that rainfall causes intermittent and predictable periods of bacteria counts above thresholds levels.

Consequently, only specially licensed Master and Subordinate diggers may harvest soft-shell clams for depuration (purification) at Marine Fisheries' Shellfish Purification Plant at Plum Island Point, Newburyport. At the Shellfish Plant, clams are purged of bacteria in clean seawater in a controlled, strictly monitored, process for two to three days until safe to eat. No recreational harvesting is allowed in these areas.

Table 5-2

Fish Species in Merrimack River Estuary

Species	Scientific Name	Species	Scientific Name
Alewife	Alosa pseudoharengus	Ninespine stickleback	Pungitius pungitius
American eel	Anguilla rostrata	Northern pipefish	syngnathus fuscus
American plaice	Hippoglossoides platesoides	Northern searobin	Priontus carolinus
American sand lance	Ammodytes americanus	Pollock	Pollachius Virens
American shad	Alosa sapidissima	Rainbow smelt	Osmerus mordax
Atlantic cod	Gasud morhua	Red hake	Urophycis Chuss
Atlantic herring	Clupea harengus	Rock gunnel	Pholis gunnelus
Atlantic mackerel	Scomber scombrus	Shorthorn sculpin	Myoxocephalus scorpius
Atlantic menhaden	Brevoortia tyrannus	Shortnose sturgeon	Acipenser brevirostrum
Atlantic salmon	Salmo salar	Silver hake	Merluccius bilinearis
Atlantic sturgeon	Acipenser oxyrhynchus	Silversides	Menidia species
Atlantic tomcod	Microgadus tomcod	Skates	Raja Species
Blueback herring	Alosa aestivalis	Smooth flounder	Pleuronectes putnami
Bluefish	Pomatommus saltatrix	Striped bass	Morone saxatilis
Butterfish	Peprilus triacanthus	Threespine stickleback	Gasterosteus aculeatus
Cunner	Tautogolabrus adspersus	White hake	Urophycis tenuis
Fourspine stickleback	Apeltes quadracus	White perch	morone americana
Grubby	Myoxocephalus aeneaus	Windowpane flounder	Scopthalmus aquosus
Longhorn sculpin	Myoxocephalus octodecemspinosus	Winter flounder	Pleuronectes americanus
Mummichog	Fundulus hetroclitus		

The sources of the bacteria are thought to be upstream untreated river discharges (CSOs, stormwater and non-point sources) and local non-point sources. Also, the area within the influence of the Newburyport wastewater treatment facility and Amesbury wastewater treatment facility remains closed to shellfishing.

Swimming

There is a public beach at the Lowell Heritage State Park, along Pawtucket Boulevard. This beach is upstream of the Lowell CSOs and most of the City's stormwater discharges. Accordingly, this beach is generally only impacted by pollutant sources upstream of the City and out of the study area. Bacteria are used as an indicator to identify the potential health risks to swimmers. Under the WQS, no single E. coli sample shall exceed 235 colonies per 100 milliliters. Flags indicating water quality and are posted at the Lowell Heritage State Park Beach and UMass Lowell Bellegarde Boathouse (upstream of beach).

There are no designated swimming areas on the lower Beaver Brook, Concord River or Merrimack River below Lowell's CSOs. Two public parks – Salisbury Beach State Reservation and Plum Island Point – at the mouth of the Merrimack River allow ocean swimming. However, signs at both parks explicitly prohibit swimming in the river. At Salisbury, a sand beach exists along the Merrimack during low tide; however, the concrete seawall above the beach is painted with "Danger – Swimming Prohibited."

At Plum Island, signs at the parking lot entrance explicitly prohibit swimming in the river.

Swimming in the receiving waters in Lowell is generally limited by existing physical conditions. There is limited access to the receiving waters along the south bank of the Merrimack River and along both banks of the affected segments of the Concord River and Beaver Brook because of existing development (i.e, buildings directly on the river banks). There is access to the north bank of the Merrimack River; however, high river velocities limit most reasonable access to the river for swimming or wading.

Swimming along the Merrimack River, downstream of Lowell, is also partially limited by safety concerns due to the physical conditions along the riverbanks. The river is powerful with a strong current and lacks natural beach areas. Swimming would be most likely to occur during low flow periods in localized areas, such as from private docks or near the ocean.

Boating

Canoeing, kayaking, and motorized boating are popular activities on the lower Merrimack River. Boat launches are available at several parks, including at Lowell Heritage State Park and by the Lowell Wastewater Treatment Plant and numerous others in towns downstream such as Tewksbury, Haverhill, and Newburyport. Some residences have private boat docks as well. Some white water boating also occurs on the Concord River.

In Massachusetts, the same water quality standards apply for boating as for swimming. Therefore, as described above, the CSOs cause the lower Merrimack River to be unsafe for boating periodically due to fecal coliform limit violations.

Water Supply

There are no municipal water withdrawals for drinking water from the lower segment of the Concord River or Beaver Brook. However, Tewksbury, Andover and Methuen draw all or part of their drinking water supply from the Merrimack River below Lowell. There are no public water supplies on the

Merrimack River downstream of Lawrence. The tidal excursion and, hence, salt water reaches up the Merrimack River through Amesbury on normal tides, and potentially further during high tides or storm surges.

The city of Haverhill is in the initial stages of considering a new supply, which may include a new water withdrawal from the Merrimack River but, would not be a direct intake from the Merrimack River. Haverhill does not have a definite plan at this current time.

5.4.3 Status of River Water Quality

Section 303(d) of the CWA requires each state to periodically review and identify those waterbodies that are not expected to meet surface water quality standards after the implementation of technology-based controls. Water bodies and uses that are impaired by water quality issues are included on the 303(d) list, which is also referred to as the Integrated List of Waters. The CWA requires that states develop a total maximum daily loads (TMDL) assessment to determine what pollutant loads are acceptable to maintain water quality standards and/or receiving water uses.

Beaver Brook, the Concord River and the Merrimack River downstream of Lowell are all on the 2013 303(d) list, the latest list available. Table 5-3 presents the information from the state's 303(d) list. The 303(d) list does not identify the sources of the impairment.

In 2005, MassDEP completed a draft TMDL for pathogens for the Merrimack River. The draft TMDL found the sources of bacteria in the Merrimack River watershed were many and varied. Most of the bacteria sources are believed to be stormwater related, but also included failing septic systems, CSOs, sanitary sewer overflows (SSO), sewer pipes connected to storm drains, certain recreational activities, wildlife including birds along with domestic pets and animals and direct overland storm water runoff.

The draft TMDL could not accurately estimate the existing sources to determine the control approach. For the illicit connections to the stormwater system and/or direct discharges to the river, the goal is complete elimination (100 percent reduction). This should be accomplished through the Phase II NPDES Stormwater program for the municipal separate storm sewer system (MS4s) permittees along the river. There are no known illicit connections in Lowell.

For wet weather conditions, target bacteria load reductions were estimated using typical storm water bacteria concentrations. This analysis indicated that a pollutant load reduction of two to three orders of magnitude (i.e., greater than 90 percent) of stormwater fecal coliform loading would be required to meet the bacteria standard. The draft TMDL determined that the goal should be accomplished through implementation of best management practices, such as those associated with the nine minimum controls and Phase II control program for stormwater.

The draft TMDL proposed a Waste Load Allocation (Limit) for CSO discharges to meet the state WQS. The TMDL targets a discharge with a bacterial level not to exceed a geometric mean of 200 organisms in any set of representative samples and shall not have more than 10 percent of the samples exceed 400 organisms. The state has not issued a final TMDL for the Merrimack River.